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NATIONAL PARK

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PINK TERRACES. MAMMOTH HOT SPRINGS GARDINER'S RIVER.

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1878
Vol.2

TWELFTH ANNUAL REPORT

OF THE

UNITED STATES

GEOLOGICAL AND GEOGRAPHICAL SURVEY

OF

THE TERRITORIES:

A REPORT OF PROGRESS OF THE EXPLORATION IN

WYOMING AND IDAHO

FOR THE YEAR 1878.

IN TWO PARTS.

PART II.

BY F. V. HAYDEN,
UNITED STATES GEOLOGIST.

CONDUCTED UNDER THE AUTHORITY OF THE SECRETARY OF THE INTERIOR.

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TWELFTH ANNUAL REPORT

OF THE

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PART II.

YELLOWSTONE NATIONAL PARK.

GEOLOGY—THERMAL SPRINGS—TOPOGRAPHY.

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LETTER TO THE SECRETARY.

OFFICE OF THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES,
Washington, D. C., February 1, 1883.

SIR: In presenting what may be regarded as a very complete report on the Yellowstone National Park it may be proper to preface it with a brief history of its inception, at least so far as it relates to this Survey.

The first exploration of the region in which the Park is now located, by the Survey under my charge, was made during the season of 1871. It was continued under more favorable auspices in 1872. Prior to that time no regular scientific examination had been made, but several private parties had visited it. In the Annual Report for 1871 I gave a brief sketch of their explorations.

In 1869 Messrs. Cook and Folsom, of Montana, ascended the Valley of the Yellowstone River to the lake, and thence over the divide into the geyser basin of the Madison River. They made no special report of this trip. A second party, under General Washburn, surveyor-general of Montana, penetrated to this region in the summer of 1870. He was accompanied by N. P. Langford and Lieut. G. C. Doane of the United States Army. Both these gentlemen gave to the world most interesting accounts of the wonders of this region, which excited much attention.

A rapid reconnaissance of the Yellowstone district was made by Col. J. W. Barlow, United States Engineers, during the summer of 1871, and an interesting report was published the following spring.

The results of the surveys under my charge during the years 1871 and 1872 were published in the form of two annual reports with illustrations and maps. Though the maps were not based upon a careful triangulation, and were not, therefore, entirely accurate, they were a great advance upon any work which had been performed previously in this region.

The exploration of the Yellowstone region, in 1871, together with the reports upon it, excited so much attention throughout the country that Congress, during the session of 1871 and 1872, became very much interested in its preservation. Numerous articles which were published by the periodical press, aided very much to increase this interest among the people. So far as is now known, the idea of setting apart a large tract about the sources of the Yellowstone River as a national park, originated with the writer.

On the 18th of December, 1871, a bill was introduced into the Sen-

ate of the United States by Hon. S. C. Pomeroy. At about the same time a similar bill was presented to the House of Representatives by the Hon. William H. Claggett of Montana. This bill was referred to the Committee on Public Lands in both houses and was reported upon favorably. In due time it passed both houses with very little opposition, and by the signature of the President became a law. In the Annual Report for 1871 the report and the law are printed in full, and are also repeated in Dr. Peale's report in this volume. I will here add the report prepared by the writer, at the request of the Secretary of the Interior, for the use of the Committees on Public Lands:

THE YELLOWSTONE PARK.

Mr. DUNNELL, from the Committee on the Public Lands, made the following report:

The Committee on the Public Lands having had under consideration bill H. R. 764, would report as follows:

The bill now before Congress has for its object the withdrawal from settlement, occupancy, or sale, under the laws of the United States, a tract of land 55 by 65 miles, about the sources of the Yellowstone and Missouri Rivers, and dedicates and sets it apart as a great national park or pleasure-ground for the benefit and enjoyment of the people. The entire area comprised within the limits of the reservation contemplated in this bill, is not susceptible of cultivation with any degree of certainty, and the winters would be too severe for stock-raising. Whenever the altitude of the mountain districts exceeds 6,000 feet above tide-water, their settlement becomes problematical unless there are valuable mines to attract people. The entire area within the limits of the proposed reservation is over 6,000 feet in altitude, and the Yellowstone Lake, which occupies an area 15 by 22, or 330 square miles, is 7,427. The ranges of mountains that hem the valleys in on every side rise to the height of 10,000 and 12,000 feet, and are covered with snow all the year. These mountains are all of volcanic origin, and it is not probable that any mines or minerals of value will ever be found there. During the months of June, July, and August the climate is pure and most invigorating, with scarcely any rain or storms of any kind; but the thermometer frequently sinks as low as 26°. There is frost every month of the year. This whole region was, in comparatively modern geological times, the scene of the most wonderful volcanic activity of any portion of our country. The hot springs and the geysers represent the last stages—the vents or escape-pipes—of these remarkable volcanic manifestations of the internal forces. All these springs are adorned with decorations more beautiful than human art ever conceived, and which have required thousands of years for the cunning hand of Nature to form. Persons are now waiting for the spring to open to enter in and take possession of these remarkable curiosities, to make merchandise of these beautiful specimens, to fence in these rare wonders, so as to charge visitors a fee, as is now done at Niagara Falls, for the sight of that which ought to be as free as the air or water.

In a few years this region will be a place of resort for all classes of people from all portions of the world. The geysers of Iceland, which have been objects of interest for the scientific men and travelers of the entire world, sink into insignificance in comparison with the hot springs of the Yellowstone and Fire-Hole Basins. As a place of resort for invalids, it will not be excelled by any portion of the world. If this bill fails to become a law this session, the vandals who are now waiting to enter into this wonder-land will, in a single season, despoil beyond recovery these remarkable curiosities, which have required all the cunning skill of Nature thousands of years to prepare.

We have already shown that no portion of this tract can ever be made available

for agricultural or mining purposes. Even if the altitude and the climate would permit the country to be made available, not over fifty square miles of the entire area could ever be settled. The valleys are all narrow, hemmed in by high, volcanic mountains, like gigantic walls.

The withdrawal of this tract, therefore, from sale or settlement takes nothing from the value of the public domain, and is no pecuniary loss to the government, but will be regarded by the entire civilized world as a step of progress and an honor to Congress and the nation.

DEPARTMENT OF THE INTERIOR,
Washington, D. C., January 29, 1872.

SIR: I have the honor to acknowledge the receipt of your communication of the 27th instant, relative to the bill now pending in the House of Representatives dedicating that tract of country known as the Yellowstone Valley as a national park.

I hand you herewith the report of Dr. F. V. Hayden, United States geologist, relative to said proposed reservation, and have only to add that I fully concur in his recommendations, and trust that the bill referred to may speedily become a law.

Very respectfully, your obedient servant,

C. DELANO,
Secretary.

Hon M. H. DUNNELL,
House of Representatives.

The committee, therefore, recommend the passage of the bill, and on motion of Mr. Dawes it passed without amendment.

This brief *résumé* of the history of the legislation in regard to the Park is repeated here for the purpose of again placing on record the real actors in this important movement. It was at the suggestion and under the direction of the writer that all the papers, maps, reports, and the law were prepared, that set this large tract of land apart for the benefit of the people. Had the subject not been brought vigorously before Congress at that particular time, and had Congress not acted promptly at that session, it would not have been possible at any subsequent period. Within one year from that time, every important locality in the large area now known as the Park, would have been taken possession of under the pre-emption laws of the United States. Thus the wisdom of the prompt action of Congress during the winter of 1871 and 1872, is clearly shown.

TOPOGRAPHICAL AND GEOLOGICAL MAPS.

In this report will be found a series of maps comprising most of the topographical work of the Survey during the years 1877 and 1878. The following statements in regard to the maps are taken from the valuable notes of Mr. Henry Gannett:

This series comprises a sketch of the primary triangulation, and a drainage map, each covering the whole area surveyed, on a scale of eight miles to an inch, a detailed map of the Yellowstone National Park, on a scale of two miles to an inch, and three detailed atlas sheets, on a scale of four miles to an inch.

The triangulation sheet shows the scheme of the primary triangulation, the stations, the sight lines, the closed and open triangles, the details of the expansions from the bases and the astronomical connections.

The base lines were two in number, one near Fort Steele, on the Union Pacific Railroad, Wyoming, the other in the valley of Bear River, near the village of Georgetown,

Idaho. Each was between 5 and 6 miles in length, about 2 miles of which appear to have been measured directly, while the balance was ranged out by small, well proportioned triangles. The expansions were by means of closed triangles, and apparently were well executed. The astronomical connections were ample, consisting of stations at Sherman and Fort Steele in Wyoming, Salt Lake City and Ogden, in Utah. These points were located by the Coast Survey and by Lieutenant Wheeler of the Engineer Corps. The scheme is well planned, most of the triangles being well proportioned, and the only failures are unquestionably due to the incompleteness of the work, owing to the abrupt discontinuance of the survey.

Since the discovery of the wonders of the Yellowstone country, in 1870, this region has been a favorite field of exploration. Expedition after expedition has traversed it, each following much the same routes as its predecessors, and, after the first, adding but little to the sum of human knowledge regarding this strange fire-ridden country.

The explorations in this region by this Survey, in 1871 and 1872, were singularly prolific of facts, geological, physical and geographical, and little that was new was evolved from numerous expeditions that followed. The big nuggets had been taken, and nothing but a careful, scientific, reworking of the tailings would extract from them the wealth of fine gold which they still held.

In 1878, this Survey reached this region in the prosecution of its system of surveys. Its work had, years previously, passed from the reconnaissance stage to that of systematic surveys on a scale and of a degree of accuracy commensurate with the needs of the country.

In that year a party was directed to make a detailed survey of the Yellowstone Park, its geography, geology and volcanic phenomena.

A part of the results of this season's work is now before the world, in the form of a map of the Yellowstone Park on a scale of two miles to an inch, a scale sufficiently large to show all details necessary to the geologist or the traveler. The topography is represented by contour lines, at approximate intervals of one hundred feet. This map, as well as the others published by this Survey, are admirable illustrations of relief-effect by means of contours; and they not only express the relief, but the absolute and relative elevations.

From a study of this map, we find that the greater part of the surface of the Park consists of high rolling plateaus, broken by stream beds, cliffs and cañons. Several small groups of mountains diversify the surface, among them the Red Mountains, in the southern part, rising 2,000 feet above the general level, or more than 10,000 feet above the sea, and the Washburn group, near the middle of the Park. This group has the form of a horseshoe, opening towards the east. The eastern border of the Park is occupied by a high rugged range, to which has long attached the name of Yellowstone Range. Index Peak, the highest measured peak in this range, exceeds 11,700 feet in height. In the northwestern corner of the Park is the southern extremity of the Gallatin Range, culminating in Electric Peak, a magnificent summit, 11,155 feet above the sea, which overlooks almost the whole Park.

The mean elevation of this reservation appears to be not far from 8,000 feet, an elevation so great in this latitude as to presuppose an almost arctic climate. The lowest point within its limits is at the mouth of Gardiner's River, on the Yellowstone, which is 5,360 feet.

Marked features of the reservation are the low, indefinite divides and the abundance of lakes and marshes. In several cases we note marshes extending across divides and making "two ocean rivers," phenomena by no means as uncommon as are popularly supposed. The lakes, principal among which are Yellowstone, Shoshone, Lewis and Heart, cover nearly 200 square miles out of the total area of the Park, which is estimated at 3,312 square miles.

Many newly discovered groups of hot springs and geysers appear, for the first time, on this map, among which should be mentioned the large and fine groups near the head of Gibbon's Fork of the Firehole, the discovery of which has been previously noticed.

The three regular topographical atlas sheets are on the same scale (4 miles to the inch) as those in the Colorado Atlas. These sheets illustrate portions of Wyoming, Idaho, and Utah. Each of them covers $2\frac{1}{2}^\circ$ of longitude and $1\frac{1}{2}^\circ$ of latitude, and includes an area of about 11,000 square miles.

The southeastern of these sheets covers the country from longitude 107° to 109° 30′ and from latitude 41° 45′ to 43°. It includes the barren plateaus of the continental divide, north of the Union Pacific Railroad, the valleys of the Sweetwater and Wind Rivers, and a part of the Wind River range.

The southwestern sheet lies directly west of the latter, extending to longitude 112°. It embraces the Green River Basin, and, farther westward, a succession of parallel ranges of no great height, alternating with broad valleys drained by Bear River and branches of the Snake.

The third sheet lies north of the last, extending to latitude 44° 15′. Besides a small portion of the Snake River plains on its western edge, nearly all this area is occupied by rugged mountains. Among them may be noted the Tetons, the Gros Ventre and the northern part of the Wind River ranges.

The plan of the geographical work has been sketched in some detail in previous reports of this Survey, and, therefore, nothing more than a brief epitome will here be attempted.

The whole work is based upon a system of triangulation, carried on with an eight-inch theodolite, reading to 10″. In the scheme there were two base-lines measured, one near Fort Steele, Wyoming, the other on Bear River, in Southeastern Idaho. Each of these was between 5 and 6 miles in length. The mean error of closure of the triangles in the expansion was 3″.5. The sides ranged from 20 to 70 miles in length. Altogether, forty-nine points were located by the primary triangulation.

Secondary triangulation was carried on by a theodolite reading to minutes. The mean error of closure of secondary triangles is 3′.

The topography was secured from elevated points by map sketches made on an assumed scale, with distances and angles estimated, and by perspective sketches, on which the topographical features were represented as they appeared to the observer at his station. All salient points in the landscape, peaks, angles of plateau, minor summits and hills, and junctions of streams, were located by intersections of sight lines from two or more stations; and, in plotting the maps in the office, the map-sketches are corrected by these locations. On these three sheets, about 3,300 points, including stations, were located, being one in every ten square miles. Altogether, between 600 and 700 stations were occupied, or about one in each 50 square miles.

A few words as to the measurements of heights, and the method of construction of contour lines. Elevations were measured by means of the barometer, and the vertical circle of the theodolite. Camps, stations, and all salient points on the routes traversed were measured by the former instrument. Aneroids were used but little and the results accepted with great caution. The vertical circle was used in determining the relative heights of all points within range of the stations—all peaks, passes, gaps, heads of spurs, &c., in short, everything that could be located, even approximately. Thus the heights of a great number of points were easily determined, and these, placed upon a perspective sketch, which may be supposed to be reasonably accurate, indicate approximately the heights of all portions of the sketch.

Difference of heights are expressed on these maps by contours. The space between two of these grade curves represents a difference of elevation of 200 feet. Where the slopes are gentle the curves are far apart, while among the cliffs of the mountains and plateaus they are crowded together, in many places being almost run into a single line. These curves are not "run," nor are they accurately located, as would be done in a minute survey. They do, however, express the orography, and, approximately, the elevation, over the whole map. They are constructed mainly from the perspective sketches, aided and directed by the measured heights. As an example of the method of their construction, take a mountain spur, starting from the peak and extending to the valley below. Its summit and base, and each point of change of slope, are located,

and their heights are known; we have also a profile sketch of the spur. Given these data, and what is easier than to distribute the curves, with a considerable approach to accuracy, between those points actually determined?

This method of representing orography is a strictly natural one. Supposing the light to be vertical, grade curves must necessarily produce the same lights and shades as in nature. All the details of the topography, down to forms not above 200 feet in height, may be expressed.

For maps for the representation of geological outcrops and formations, these grade curves are invaluable. They enable the geologist to draw accurately the outcrops not only of horizontal, but of inclined strata, over vast areas, from a few isolated observations. In many cases, by thus expressing the orography of a range, the key to its geological structure is supplied.

Extended notices of these maps, both topographical and geological, were published in the American Naturalist for January and March, 1880; and a small edition of them was distributed to working geologists and scientific societies in this country and in Europe.

These maps, as well as those of the Colorado Atlas, were engraved by Mr. Julius Bien, of New York City, and they have justly been regarded as among the finest specimens of cartography ever published in this or any other country.

For the main geological features of the Park the reader is referred to the admirable report of W. H. Holmes in this volume. As he has stated in his preface, it is far from being exhaustive and many important problems are left unsolved, yet it will certainly be regarded as a real addition to our knowledge of this most interesting area. To make an exhaustive study of this geological district must be the work of years instead of a few weeks. The geological map accompanying this volume will be found to be a great improvement upon the one published in 1872. Considering the shortness of the time occupied in the field work, the detailed accuracy of the various formations is remarkable. This could have been done by Mr. Holmes only through his great skill in sketching rapidly the physical features. Some additional matter on the geology will be found in the annual reports of the Survey for 1871 and 1872.

Although most of the geological formations known to occur in the Northwest are represented in the Park, it will be observed that rocks of volcanic origin cover far the greater portion. Rhyolite predominates over all the other varieties. The areas colored as volcanic tertiaries are really conglomerates or breccias of volcanic origin, and composed mostly of volcanic rocks. In determining the variety and character of these rocks, of which Mr. Holmes made a large collection, he received the able assistance of Capt. C. E. Dutton, whose report is appended, The volcanic conglomerates form a very conspicuous feature of the Park. reaching a thickness in places of two to four thousand feet. Two of the most important ranges of mountains in this region, the Yellowstone and Washburn ranges, are almost entirely composed of these conglomerates. It will be readily seen that they open up an almost limitless field of study.

At the present time the older sedimentary groups, from the Cretaceous to the Silurian, occupy comparatively small areas; formerly they prob-

ably extended over the entire district, but are now either concealed by overlying volcanic rock or have been removed by erosion. A number of specimens of fossil plants obtained in different portions of the park in 1872, and identified by Professor Lesquereux, indicate the existence of the Laramie or Fort Union group. Numerous specimens of the genera *Populus*, *Ficus*, *Rhamnus*, *Juglans*, *Salix*, *Sabal*, &c., were found in shales or slates partially changed by contact with eruptive rocks. The map shows very clearly the character of the lake beds as well as the more modern deposits, and the report of Mr. Holmes, with his graphic illustrations, renders them very instructive. Even here, at the very sources of the largest rivers in the most elevated areas of the West, the water area of the lakes has diminished nearly one-half, as the old outline shows. The restoration of the ancient lakes in the dry region of the Great Basin, by Mr. G. K. Gilbert, present remarkable examples of the difference in size between the ancient condition and the present.

Dr. Peale's report on thermal springs gives a detailed description of all the springs and geysers, of any importance, found in the Yellowstone National Park. On the maps of the different geyser basins accompanying his report, the springs are indicated by numbers which correspond with those given to them in the text, so that hereafter there ought to be no difficulty in identifying the individual springs and geysers.

The descriptions of the geysers include observations made since 1878, up to and including those made in the year 1881.

Dr. Peale spent about one month in actual work on the springs and geysers, a considerable portion of this time being devoted to assisting Mr. Mushbach, who did the topographical field work for the preparation of the maps. The rest of the time was occupied in studying the various spring areas. He describes and tabulates over 2,000 springs and 71 geysers. The most interesting of these are shown in the plates and figures illustrating his report. It ought never to be necessary to repeat this preliminary work in the Park. What remains to be done is to start a series of close and detailed observations protracted through a number of consecutive years, with a view to determine, if possible, the laws governing geyseric action.

In the second part of his report he brings together, in a few brief chapters, short descriptions of the thermal springs of the globe, tracing their connection with volcanic action, dwelling more particularly on the Iceland and New Zealand regions.

In his third part, under the title thermo-hydrology, he takes up the general subject of thermal springs, the color of water, source of heat, &c., and compares the Yellowstone National Park with other hot-spring areas, especially those of Iceland and New Zealand. Chapters are included giving the analyses of the waters and deposits from the springs of the Park, and the last section is devoted to the special consideration of geysers, giving the theories and treating of the peculiarities of their eruptions and the influences modifying them.

In the bibliographical appendix the bibliography of the Yellowstone National Park is brought down to February, 1883. Bibliographies of Iceland and New Zealand and lists of authorities for the tables of thermal springs (in the second part) are also given. The mineralogical appendix contains a list of minerals of the Park and analyses of several of the great variety of igneous rocks found within its limits.

The topographical map of the Park, by Mr. Henry Gannett, has already been referred to. It is an excellent example of his accuracy and skill in this kind of work, both in the field and in the office. Mr. Gannett was one of the most faithful and energetic members of the Survey for several years, and his reports upon a variety of topics were of a high order. His geographical report in this volume is a model of conciseness as well as critical accuracy. So far as this subject is concerned, but little more is left to be done. All the elevations have been examined with great care, and may be regarded as substantially correct. The descriptions of the mountain ranges and drainage are minute, and the entire report will furnish much valuable matter for a guide-book of the Park. The maps of the geyser basins are as accurate and complete as will probably ever be needed.

The chromo-lighographic and lithographic illustrations in this report, by Thomas Sinclair & Son, are finely engraved and do credit to that enterprising establishment.

It remains now for me to express my cordial thanks to all the assistants that have so long and so ably aided me in the work that is now closed. I part with them with real regret. Should my health ever be restored, much additional matter now partially prepared may be given to the world.

Very respectfully, your obedient servant,

F. V. HAYDEN.

To the Hon. SECRETARY OF THE INTERIOR.

REPORT ON THE GEOLOGY OF THE YELLOWSTONE NATIONAL PARK.

By W. H. Holmes.

Office United States Geological Survey,
Washington, D. C., August 2, 1879.

Sir: Herewith I have the honor to transmit a brief report of my geologic work in the Yellowstone Park during the summer of 1878.

With a deep sense of my obligations to you for opportunities afforded, and a lively appreciation of your uniform liberality and kindness,

I remain, very sincerely, yours,

W. H. HOLMES.

Dr. F. V. Hayden,
United States Geologist.

INTRODUCTORY.

In presenting a report upon the geology of the Yellowstone Park, I feel it incumbent upon me to state, candidly, a few facts in regard thereto.

It is well known that already three or four reports have been written which dwell to some extent upon the geology of the Park, and it may be asked why another report is to be prepared upon this region.

It is probably not generally known that the so-called "Yellowstone country" over which the early explorations were carried, comprises an area of not less 10,000 square miles; neither is it known that the time spent in collecting the data embodied in any one of these reports falls short of 90 days duration, nor that the geology of this whole region is more varied and complicated than that of any equally large area in the Rocky Mountains.

With these facts in view, however, it will not seem strange that up to this time geologists have but glanced at the surface features of the country, and that the more profound and intricate problems remain almost untouched.

With regard to my own work, I wish to state that if I could have consumed years instead of months in the study of the 3,400 square miles comprising the Park, I might justify myself in putting my observations on paper. Scarcely two months were passed within the Park, and during nearly one-half of this time storms of rain and snow prevailed to such an extent as to greatly interfere with the work. I have, consequently, gone just far enough to get glimpses of the splendid problems of the rocks, and to enable me in the future to appreciate and understand the classic chapter that this district will some day add to the great volume of written geology.

In order that those who follow me may be able to utilize the many facts already gathered, I have indicated in most cases the routes followed, and pointed out the exact localities at which observations were made. In arranging my report I have taken up a number of the more important localities as topics, and treated each one as fully as possible before passing on to the next. The order of succession is pretty nearly such as would naturally be adopted by the observer who approaches the Park from the north by way of the Yellowstone Valley.

To discuss the geologic formations in the order of their age would involve too much skipping about for convenient reference, besides such treatment is not suited to the presentation of fragmentary data.

A large collection of hand specimens of the igneous rocks of the Park was made, and about 30 specimens have been submitted to Capt. C. E. Dutton for microscopic examination. I wish here to express my obligations to him for the report which he has kindly furnished, as well as for valuable assistance in the study of the general lithologic characters of the collection.

I am under obligations to Dr. A. C. Peale for observations made in the southwest corner of the Park before my arrival, as well as for other notes on the geology of such localities as his study of the hot springs enabled him to visit.

I am also under obligations to Mr. Henry Gannett, director of the party, for the most generous co-operation and assistance.

NARRATIVE.

Shortly before leaving Washington it was definitely arranged that I should join Mr. Gannett's party, and carry on the geologic work of the Park Division, Dr. A. C. Peale, the regular geologist of that division, having been assigned to the duty of making a detailed survey of the thermal springs of that region. In order, however, that I might have the opportunity of visiting the Wind River and Teton Mountains for the purpose of making panoramic views, I was permitted to join the primary triangulation party, under Mr. Wilson, at Point of Rocks, Wyoming, and remain with it until we should reach the east base of the Teton Range.

From the summits of Wind River and Fremont's Peaks I obtained good views of the superb range to which they belong, and besides this made many sketches amongst the remarkable glacial regions of the western slope.

Having reached the Snake River Valley, Mr. Wilson was compelled to cross the Teton Range, for the purpose of ascending the Grand Teton from the west; I therefore joined the photographic party under the direction of Mr. W. H. Jackson, and accompanied him up the broad valley of the Snake to the base of the Upper Gros Ventre Butte. From both Upper and Lower Gros Ventre Buttes I made sketches of the magnificent range to the west. The hazy condition of the atmosphere rendered sketching difficult and photography almost impossible, but imparted to the mountains themselves additional grandeur and assisted in confirming our previous impression that this range is the finest in the Rocky Mountains.

Taking leave of Mr. Jackson's party at the base of the Grand Teton, I made all haste to join Mr. Gannett's party in the Yellowstone Park.

Plate I.—Yellowstone Lake. View from Signal Point, showing Promontory Point.

My agreement had been to meet the latter party at the head of Shoshone Lake on the 15th of July, but it was the 17th before I was able to leave Mr. Jackson's camp. Taking with me Mr. F. M. Amelung and Mr. S. D. Hovey, I ascended the valley of the Snake to the outlet of Jackson's Lake, making during the day some additional sketches.

The Grand Teton from the northwest is exceedingly fine, and Mount Moran, which rises from the west side of the lake, is a grand and interesting peak. The clouds obscured the summits of these peaks during the entire day and prevented satisfactory sketching.

We were prevented from making long marches by the sickness of Mr. Hovey, and at the end of the second day were forced to go into camp quite early at the forks of the Snake. On the morning of the 20th we ascended the ridge between the two branches of the Snake, and before noon reached the foot of Lewis Lake. Crossing the river at the point of its exit from the lake, we ascended the densely timbered ridge to the west and struck out to the northwest across a high timbered plateau. Late in the afternoon we came out upon an open valley through which flowed a large creek. On the north side of this valley lies a low wooded ridge, beyond which could be seen portions of Shoshone Lake. Crossing the valley and still keeping to the northwest, we soon arrived at the southwest end of the lake, and after an hour's hard struggle with timber and swamps reached the camp of Mr. Gannett's party in the Geyser Basin. Dr. Peale was already at work making surveys of the Shoshone Geyser Basin. He had reached this point five days previously, in company with Mr. Gannett, and up to that time had been making geologic examinations in the southwestern part of the Park.

Mr. Gannett had left the main camp on the morning of the 19th, accompanied by Mr. Thomas Cooper, for the purpose of continuing his topographical work along the southern border of the Park, and it was thought by his companions in the main camp that on the 21st he would probably ascend some one of the higher summits of the Red Mountain Range. Wishing to join him as soon as possible, and feeling the importance of taking advantage of every opportunity to examine the geology of this part of the Park, I set out alone on the morning of the 21st, outfitted with a pair of blankets and provisions for two days. I felt confident that I could find him within that time, or, if otherwise, I should be able to spend the 22d on Mount Sheridan and return to camp on the 23d. During the day I traveled steadily through the forest in a southeast direction, passing to the south of Shoshone Lake and touching the northeast corner of Lewis Lake. Twenty miles of travel brought me to the base of the mountains, and just before sundown I passed out of the timber, climbed up the steep west face and out upon one of the northern summits of the range. I had given up the idea of seeing Mr. Gannett that day, and intended, after taking a glance around to determine on to-morrow's work, to descend to a little park that nestled at the west base and camp for the night. While looking about with my glass I noticed that a topographical monument had been built on the summit of Mount Sheridan, which lay about a mile to the east, and on looking a second time was both surprised and delighted to discover two men darkly outlined against the sky. A little later I joined my friends, and hastening down the precipitous northern face encamped with them at the head of Heart Lake.

While in this vicinity we visited Flat Mountain and made some examinations among the numerous groups of geysers and hot springs that occur in this region. One little cluster of springs that lies near the shore of the lake possesses a peculiar interest in having been for a number of

days a place of rest for Mr. Evarts, who was lost for a number of weeks in the Park in 1870.

On the 24th I reascended Mount Sheridan for the purpose of finishing my observations and sketches. On the following evening we joined the main party at Shoshone Lake.

It became necessary, on account of want of supplies, to hasten to Gardiner River Springs. We crossed first to Bechler's Fork and thence to the Madison River. Descending this, we visited the Geyser Basins, and worked as far to the west as the plateau west of Gibbon's Fork. Ascending the East Fork of the Madison, we reached the Yellowstone River at Crater Hills and carried our investigations down the left bank of the river to the Falls, thence down the cañon, across Mount Washburne, and, by way of Baronett's Bridge, to Mammoth Springs.

While camp remained at the springs we visited Sepulchre Mountain, Electric Peak, and Mount Evarts, and on the 12th of September set out for the East Fork and Yellowstone Lake. Our work went on with good success until the 23d of September, when a series of snow storms set in. Our work was much retarded, and finally, on the 13th of October, we were compelled to forego further work in the Park and make all haste for Bozeman, Montana, which place we reached on the 18th.

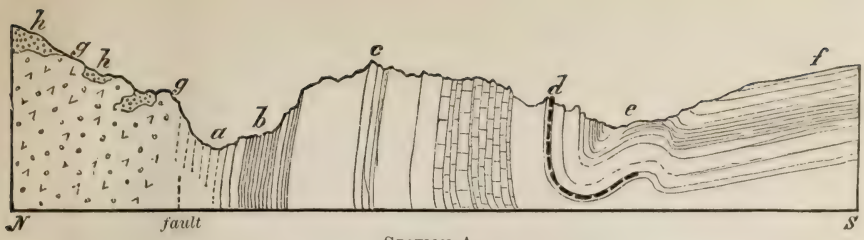
GENERAL SURFACE FEATURES.

The surface features of the Park present a great diversity of character. A general impression prevails amongst people who have derived their knowledge from books and newspaper reports, that the Park abounds in grand scenery. On the contrary, the greater part consists of undulating and broken table-lands, densely timbered and extremely monotonous. There are, however, along the north and east, bordering ranges of lofty and picturesque mountains, and the cañons which cut their way through the table-lands and along the bases of the ranges possess a very deep interest.

A large part of the Park, especially that bordering the Yellowstone River and its chief tributaries, is of the attractive parked country so characteristic of the less rugged upland valleys of the Rocky Mountains.

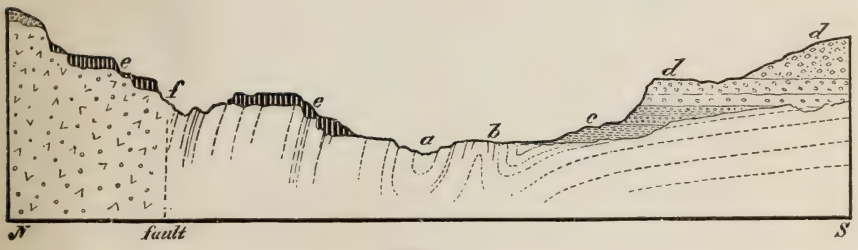
The drainage of the Park area is divided between three distinct systems—the Yellowstone River, which has about three-fifths, and the Madison and Snake Rivers, which have about one-fifth each. The Yellowstone River runs in a sinuous course from the southeast to the northwest corner of the Park, and in the upper half of its course is in open valleys. In the northern half, that is to say, from the Falls to the mouth of Gardiner River, it is almost continually in cañons. The course of the river serves to separate, approximately, the mountain districts from the undulating and flat districts. With the exception of a belt that extends from the Lake down the east side of the cañon to the East Fork, the country east of the river is mountainous. The belt of flat land just mentioned belongs properly to the great undulating plateau that stretches out to the south and west, and which has its monotony broken by the cañons, of the various rivers and by occasional groups of mountains.

Across this monotonous district, which I shall call the Park Plateau, the ocean divide passes. Within the Park district this divide is not marked by any elevation or ridge that lifts itself above the general level. To the west, 30 miles beyond the limits of the Park, the divide sweeps across the extreme southeastern group of the Madison Mountains, and on the southeast finds its first marked elevation in the vol-



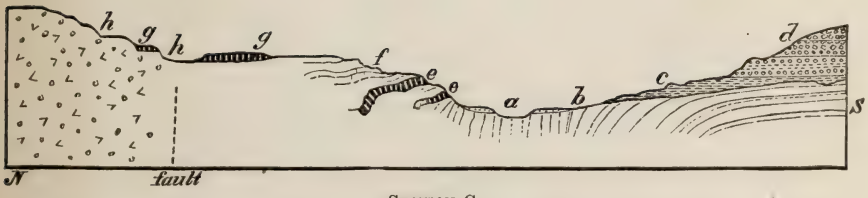
SECTION A.

a Yellowstone River. *b* Silurian strata. *c* Cinnabar Mountain. *d* Cretaceous strata.
e Crumpled strata. *f* Slope of Electric Peak. *g* Metamorphic rocks (?). *h* Fragmentary volcanic rocks.



SECTION B.

a Yellowstone River. *b* Vertical Creta. shales. *c* Tufaceous marls. *d* Volcanic conglomerates.
e Sheets of basalt. *f* Metamorphic rocks.



SECTION C.

a Yellowstone River. *b* Vertical shales. *c* Tufaceous marls. *d* Conglomerates.
e Intruded basalts. *f* Yellow and white sandstone. *g* Sheet of basalt. *h* Metamorphic rocks.

Plate II.—Geology of Yellowstone Valley.

canic ranges about the headwaters of the Upper Yellowstone. The general elevation of the Park Plateau is 7,500 to 8,500 feet. Its geological formations are entirely volcanic, and are composed for the most part of light colored rhyolites, although dark pitch-stones occur on some of the higher levels.

The Red Mountain and Washburne Ranges are the only considerable mountain masses within the limits of the plateau. Both of these ranges have steep but rounded outlines, with rudely conical summits, which rise from 3,000 to 4,000 feet above the plateau. They are of small extent, comprising areas of less than one hundred square miles. In geologic structure they are quite distinct, the Red Mountains being entirely rhyolites, while the Washburne Range is composed greatly of fragmentary materials in which the andesites and hornblendic trachytes predominate.

The great range bordering the plateau on the east—which is known as the Yellowstone Range—is also igneous, the rocks, so far as known, consisting of andesites and hornblendic trachytes. The slopes are comparatively gentle below, and are covered with heavy forests, but the summit regions, which are from 10,000 to 11,000 feet in height, abound in picturesque and striking scenery. This range connects around the head of the valley of the East Fork with the remarkable range or mass of mountains that borders the plateau on the north, and which terminates in the lofty peaks that overlook the lower valley of the Yellowstone. A great part of this range is also igneous, and consists chiefly of volcanic conglomerates, the paleozoic and metamorphic rocks appearing in many places beneath them.

The West Gallatin Range, which also comes within the Park, lies in the extreme northwest corner, and is almost exclusively sedimentary. The range is quite rugged, and its chief summit, Electric Peak, is the highest in the Park.

THE GREAT DISPLACEMENT OF THE YELLOWSTONE VALLEY.

The exposures of pre-Tertiary strata within the Park area are very limited, and but for the erosion of Yellowstone Valley no parts of the sedimentary strata would appear, excepting those which now form the higher summits of the East Gallatin Mountains. To the erosion of this valley, therefore, we owe almost all the knowledge we possess of the history of the pre-Tertiary movements. At the present stage of erosion we are able to see that at a period synchronous, probably, with the general Rocky Mountain uplift, a great displacement was produced along the line now occupied by the Yellowstone River.

How much this displacement had to do with the great events of the succeeding period it is by no means easy to determine. That it gave a natural depression which is now occupied by the valley, and that the great range of the Yellowstone rose along its northern border, are evident. Just what part of the extraordinary events that have since occurred on the thrown or depressed side, or what part of the enormous volcanic activity displayed is associated with the weak line then produced, I am as yet unable to make out. The multitude of changes that have followed, and the enormous deposition of volcanic material complicate and obscure all phenomena connected with this displacement. The only locality in which the strata involved are exposed lies along the Yellowstone Valley between Cinnabar Mountain and the valley of Blacktail-deer Creek. The extension of this displacement beyond the limits of this valley, or its connections with other displacements in neighbor-

ing districts, have not been made out. It has a strike nearly northwest and southeast. Followed to the southeast this strike would carry it through between Mount Washburne and Amethyst Mountain, and beyond this through the great volcanic range east of the lake. To the northwest it would pass beneath the volcanic mass of the main Gallatin range, and continue in the direction of the lower cañon of the Madison. This displacement, so far as exposed, is by no means a simple fault. The broken edges of the strata have become involved, and on the dropped side are much dragged and crumpled. The amount of throw or displacement at any one point is difficult to determine, owing to the fact that we were unable to cross to the north side of the river to make the necessary observations of the uplifted side. The summits of the high range to the north, as viewed from the south side of the river, are apparently, in many cases, composed of Archæan rocks, which rise to the height of 5,000 feet above the bed of the Yellowstone at Cinnabar Mountain. In the vicinity of this mountain the top of the pre-Tertiary formation of the south side of the fault are depressed to the river level. By adding 5,000 feet to the thickness of the pre-Tertiary strata we have a minimum estimate of the throw, at about 15,000 feet.

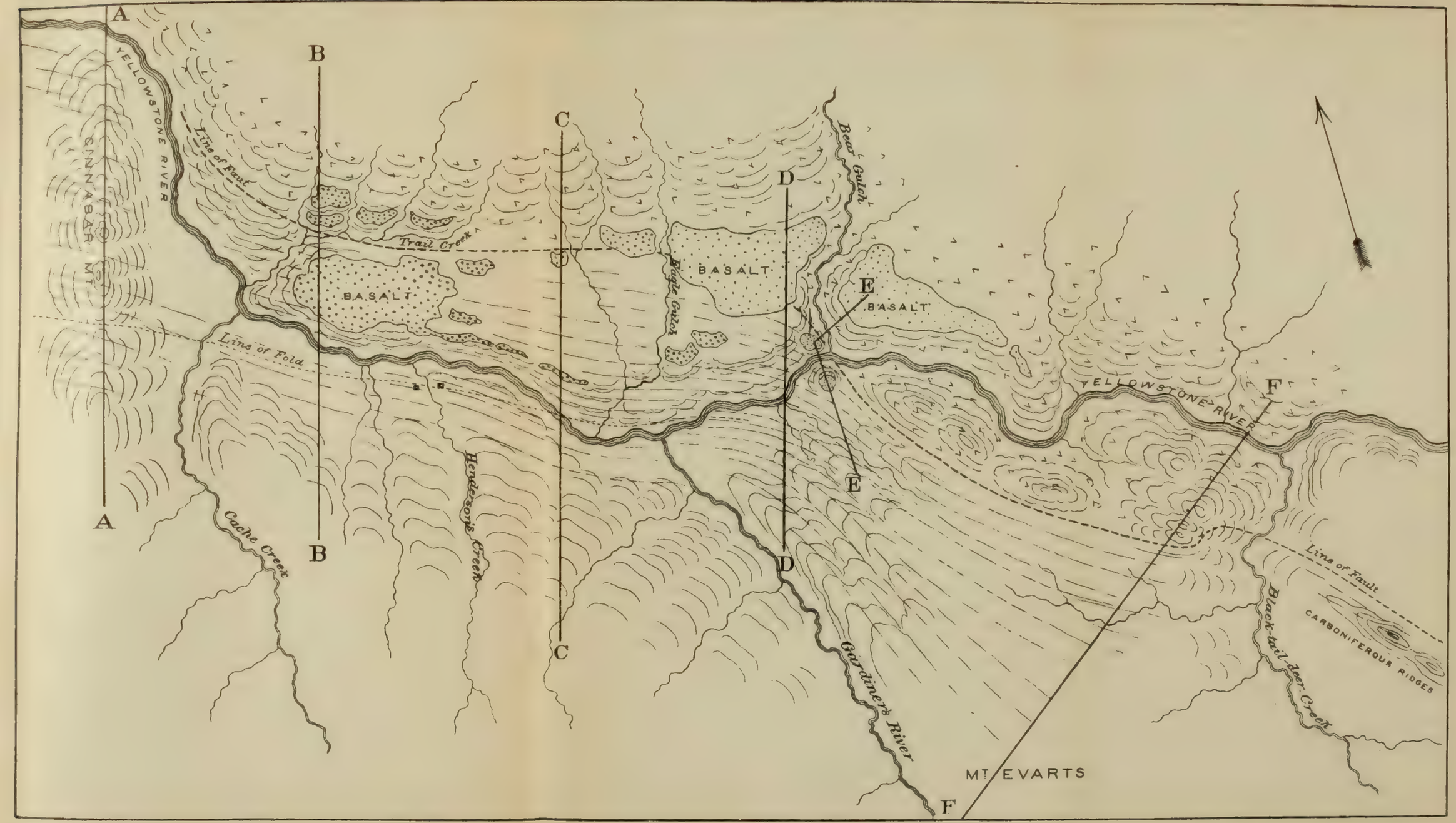
In Section A I have represented as nearly as possible the condition of the strata as seen at Cinnabar Mountain. The location of this section, as well as of those which follow, is shown on the accompanying map, Plate III. It will be seen that Cinnabar Mountain is formed of a series of strata that has been folded abruptly up along the south side of the fault, and that at *e* there has been an abrupt auxiliary displacement along which the Cretaceous strata are much crumpled. The vertical beds of the mountain comprise nearly the whole of the Mesozoic and Paleozoic rocks. At *e* we have the Middle Cretaceous shales; to the south of this the strata are but slightly disturbed, and rise in a gentle slope of from 5° to 15° to the summit of Electric Peak. South of this summit, along the crest of the Gallatin Range, the whole series of sedimentary strata rises gradually to the surface until in Mount Holmes, twenty miles south of Cinnabar Mountain, we have the Silurian strata, a series of compact limestones, which correspond in appearance to the vertical beds on the banks of the Yellowstone at *b*, Section A.

North of the river, at *g*, the rocks appear to be chiefly metamorphic. There are, however, many patches of volcanic products, some being fragmentary and others probably intrusive.

The fragment of the older sedimentary strata which forms Cinnabar Mountain, is the only one of importance exposed along the line of the displacement. In ascending the river, from the point *b* of the section, we follow an open valley along the east base of Cinnabar Mountain, and at the Cache Creek crossing reach the line of the auxiliary fold shown in Section A at *e*.

On the accompanying map the strike of the upturned strata is indicated by broken lines. The approximate line of the great displacement is represented by a heavy-dotted line, and the auxiliary fold by a light one. If the older strata which appear in Cinnabar Mountain occur on the north side of the river they are so obscured by alluvial and volcanic deposits, or so planed down by erosion, as to pass unnoticed. The Cretaceous rocks that form the river banks are much obscured by alluvial deposits, but such outcrops as occur indicate a vertical position.

As we recede from the river on the south side, the Cretaceous rocks soon disappear beneath the heavy deposit of tufaceous marls and conglomerates (*c* and *d*, Section B), which have been deposited horizontally upon the folded and eroded strata. The marls and the great series of


A
B
C
D
E
F
YELLOWSTONE RIVER
CINNABAR MT.
Line of Fault
Trail Creek
BASALT
Line of Fold
Cache Creek
Henderson's Creek
Bear Gulch
Eagle Gulch
BASALT
BASALT
YELLOWSTONE RIVER
Line of Fault
CARBONIFEROUS RIDGES
Black-tail-deer Creek
Gardiner's River
MT EVARTS

volcanic conglomerates that form the bulk of Sepulchre Mountain seem to form a continuous and unbroken series.

From the mouth of Cache Creek to the mouth of Gardiner's River the Yellowstone River remains in the synclinal fold which appears at *e* in Section A, and at *b* in Section B. The line of the fault probably runs nearly parallel to this fold, but is from one to two miles to the north. Between the river and the fault-line is a broad, irregular bench which has a general elevation of 200 or 300 feet above the river. Outcrops of shales and sandstones, the former gray and the latter yellow and white, occur all along the steep face of this bench. They have a strike nearly parallel with the river. In most cases they dip at steep angles, but in places seem to fold over the front of the bluffs and lie in a more or less horizontal position on the upper surface of the bench.

A notable feature of this bench is the very plentiful occurrence of basaltic rocks. All along the bluff face there are dark irregular seams of basalt; they do not lie conformably with the sedimentary strata but cut across at various angles as if intruded into their present position subsequently to the folding of the strata. On the upper surface of the bench, and extending back to the base of the mountain slopes, are very numerous sheets and masses of basalt, which break off in benches, the fallen portions forming dark slides of *débris*.

The smooth slopes of the mountains that rise behind the low bench have an obscure benched appearance that is doubtless partly owing to the existence of soil-covered lava-flows, but which must be chiefly the result of ancient river action.

What can be seen of the Section in the middle portion of the bench is given in Section C.

At the mouth of Bear Gulch we have some interesting features. The line of the fault here crosses the river obliquely from the north to the south side. Portions of the Cretaceous strata have been caught in the irregular wall of the ascending schists and quartzites of the north side of the fault, and appear in positions such as are indicated at *d* in Section D. Large masses of yellowish sandstone strata just west of Bear Creek now stand on edge or incline at steep angles. The Cretaceous shales and shaly sandstones which form the river banks for some distance below the mouth of Bear Creek dip at various angles and are very much dislocated. The strata near Bear Gulch are in places quite brilliant in color, probably from mineral stains which owe their presence to the action of ancient hot springs. At the junction of Bear Creek with the Yellowstone, on the right bank of the former, there is at present a small group of springs, the deposits of which extend down to the river bank. On the south bank of the Yellowstone, opposite the mouth of Bear Creek, there stands a small butte which is capped by a heavy mass of ancient calcareous hot spring deposit. The deposit is some 20 or 25 feet thick, is yellowish in color, and so compact that it has, at a little distance, the appearance of compact limestone. The base of the butte is composed of the vertical shales, and these are underlaid by the metamorphic quartzites that have risen beneath them. The antiquity of the siliceous deposit of the capping is made evident by the advanced state of erosion of the underlying strata, as well as by the fact that the summit of the butte, now at an elevation of some 200 feet above the river, is covered with huge rounded granite bowlders, which were doubtless transported from a point far up the cañon while the bed of the river was still above the level of the present summit of the butte. (See Section E.) In the bed of the river beneath the butte and forming the walls of the third cañon which extends from this point to Junction Valley, are

the hard metamorphic quartzites and quartzitic schists, the affinities of which puzzle me very much. It is not at all improbable that they consist chiefly of altered and distorted Paleozoic or even Mesozoic strata. With the exception, however, of a few fragments, which are shown at *i* in Section E, there is but slight resemblance to these formations.

The river for a short distance above Bear Creek passes over a very rough bed of dark-gray quartzites, and the water has worn deep holes in the bottom and sides. Near by, on the south side, a rugged crag rises from the river bank, on which an eagle has built its nest. From this point, as far up as the mouth of Hell Roaring Creek, the river flows over a bed of granitic rocks.

The bluffs on the north side of the river, both east and west of Bear Creek, are capped by horizontal beds of basalt, as shown in Section D. These are probably remnants of sheets which once covered a great part of the valley below.

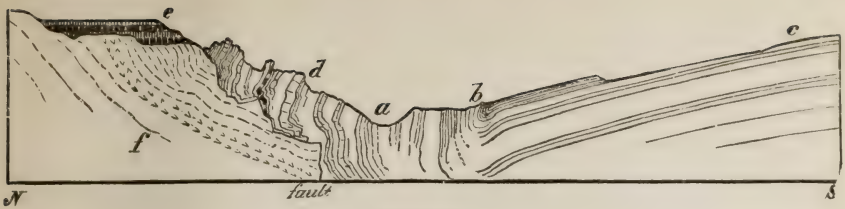
Below the mouth of Gardiner River, on the south side of the Yellowstone, we have a series of vertical strata that run almost parallel with the river. Such of these strata as appear above the deposits of drift material are sandstones, which have a greenish color, and resemble very much some of the Tertiary strata of Amethyst Mountain. At one locality near the road, and perhaps a mile below Gardiner's River, I obtained a few impressions of leaves which are considered by Professor Lesquereux to indicate the Cretaceous age of the beds. This same series of strata crosses the course of Gardiner River near its mouth and continues along the south side of the fault-line to the valley of Black-tail-deer Creek. The outcrop in a little butte that lies just above the confluence of Gardiner River and the Yellowstone, and at a number of points farther up has always a vertical position.

In tracing the displacement eastward from the mouth of Bear Creek we find that a high ridge of metamorphic rock interposes itself between the line of the fault and the cañon. This ridge is broken in two or three places by transverse drainage, but may be followed as far as the mouth of Black-tail-deer Creek. It is composed principally of schists that have a decided quartzitic character, and evidently belong to the same series as the similar formations noticed at the mouth of Bear Creek. The general appearance of the ridge indicates a stratified character parallel with the fold. The schists north of the river are, however, disconnected with the fold, as they have a strike to the north with a steep easterly dip.

Along the depression west of the ridge of quartzitic schists just mentioned the Cretaceous and possibly part of the Post-Cretaceous strata are folded back upon the strata that form the north slope of Mount Evarts. At a few points rising against the schistose ridge there are outcrops of gnarled limestones that are probably Paleozoic. They have doubtless been dragged up in the fault.

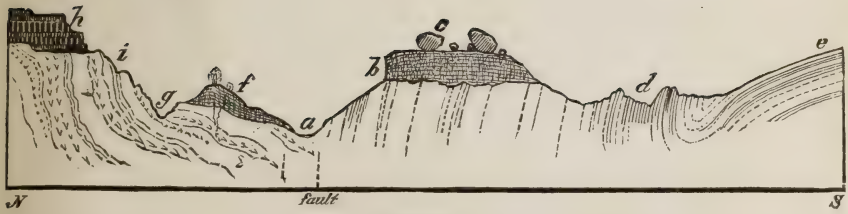
Farther on to the east we come upon a group of high, reddish hills which overlook the cañon to the north and Black-tail-deer Creek to the east. In the southern faces of these hills the characteristic Mesozoic Red Beds appear, and the Jurassic and Lower Cretaceous formations outcrop along the south base. All of these formations are vertical, or nearly so. The strike makes an abrupt turn to the north around the southeastern base of the hills, but soon returns to a southeasterly direction. Forming the summits of some of the higher points of the hills are outcrops of metamorphosed and distorted strata that have evidently been involved in the fault.

Between these hills and the highest part of Mount Evarts there are



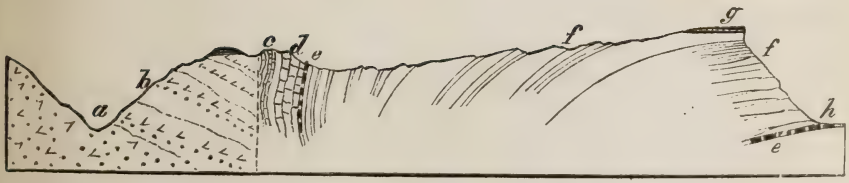
SECTION D.

a Yellowstone River. *b* Vertical sandstone. *c* Slope of Mount Evarts.
d Dragged fragments of Cretaceous strata. *e* Sheets columnar basalt. *f* Quartzites and schists.



SECTION E.

a Yellowstone River. *b* Hot Spring limestone. *c* Granite bowlders. *d* Vertical sandstones.
e Slope of Mount Evarts. *f* Hot springs and deposits. *g* Bear Gulch. *h* Basalts. *i* Quartzites.



SECTION F.

a Yellowstone River. *b* Mica-schist, &c. *c* Crumpled quartzites. *d* Red beds.
e Lower Cretaceous strata. *f* Middle and Upper Cretaceous. *g* Mount Evarts *h* Gardiner's River.

Plate IV.—Geology of Yellowstone Valley.

a series of ridges, or hog-backs, which include a duplicate set of strata produced by the folding back on themselves of the Upper Cretaceous and Post-Cretaceous (?) rocks. (See Section F.) These strata are so obscured by soil and vegetation that one can neither determine their exact character nor say just where the axis of the fold runs. As the distance is upward of three miles, and the dip mostly quite steep, the series of strata must be very large. This apparent thickness of strata makes it seem probable that they comprise, besides the Middle and Upper Cretaceous, at least a part of the Post-Cretaceous or Laramie Group.

On the eastern slope of Mount Evarts and in the valley of Black-tail-deer Creek I did not observe any outcrops of the sedimentary rocks, local drift and flows of lava covering everything up, but on the east side of the latter valley the sedimentary rocks rise above the covering of lava in two or more small ridges. As will be seen by reference to the map, these are nearly on the line of the fault and probably belong to the dragged strata of the south side. They are Carboniferous sandstones, and contain numerous characteristic fossils, amongst which the following genera are represented: *Spirifer*, *Athyrus*, *Hemipronites*, and *Productus*.

On the trail near the head of the eastern branch of Black-tail-deer Creek some sandstones occur which have also a vertical position, and a strike almost uniform with that of the more westerly outcrops. East of this, so far as my knowledge goes, there are no exposures of the rocks of the south side of the fault. The schists of the north side form the walls of the third cañon and appear in Junction Valley and in the lower part of the valley of East Fork.

MOUNT EVARTS.

In the angle between Gardiner River and the Yellowstone is a broad triangular mountain mass comprising an area of about 20 square miles, which is known by people who frequent the Park as Mount Evarts. This name has been attached to it since 1870. The story of Mr. Evarts' adventures and suffering is well known, and the fact that his rescue from a horrible death took place in a little valley just back of the summit of this mountain makes the name more than usually appropriate.

To the casual observer this mountain may not seem to be one to which he would be ambitious to attach his name; but I am free to say that as an object of interest, either to the tourist or geologist, it has not its equal in the Park, and I am quite sure that those who come once within its shadow will not soon cease to remember it as one of the most striking landmarks of the whole land of wonders.

The visitor to the springs is constantly confronted by a gigantic mountain wall that rises on the opposite side of Gardiner River to the height of 2,000 feet, and seems to close him in in a way that is almost oppressive. In the morning light and up to midday this wall is in shadow, and is almost a blank, but as soon as the sun reaches the zenith the ridges of its deeply scored face begin to appear in relief, and we have a chance to study the character of the formations and the very striking work of the erosive agents.

From the high angular point that overlooks the junction of the East Fork with the main Gardiner a broad, massive sheet of rhyolitic lava extends back to the right and left across the plateau-like summit. Fronting the springs this cap of rhyolite breaks off in a vertical wall nearly 100 feet in height. Just opposite the springs, at the highest point of the mountain, the wall terminates rather abruptly, the lower surface

rising upon the eroded edges of the Cretaceous sandstones and shales which formed the border of the flat basin into which the molten mass was poured. With the aid of a field-glass the details of the contact between the rhyolite and the Cretaceous strata can be pretty clearly made out, but the curious white line, bordered by a ferruginous belt, which occurs along the contact, must be examined more closely to be fully understood.

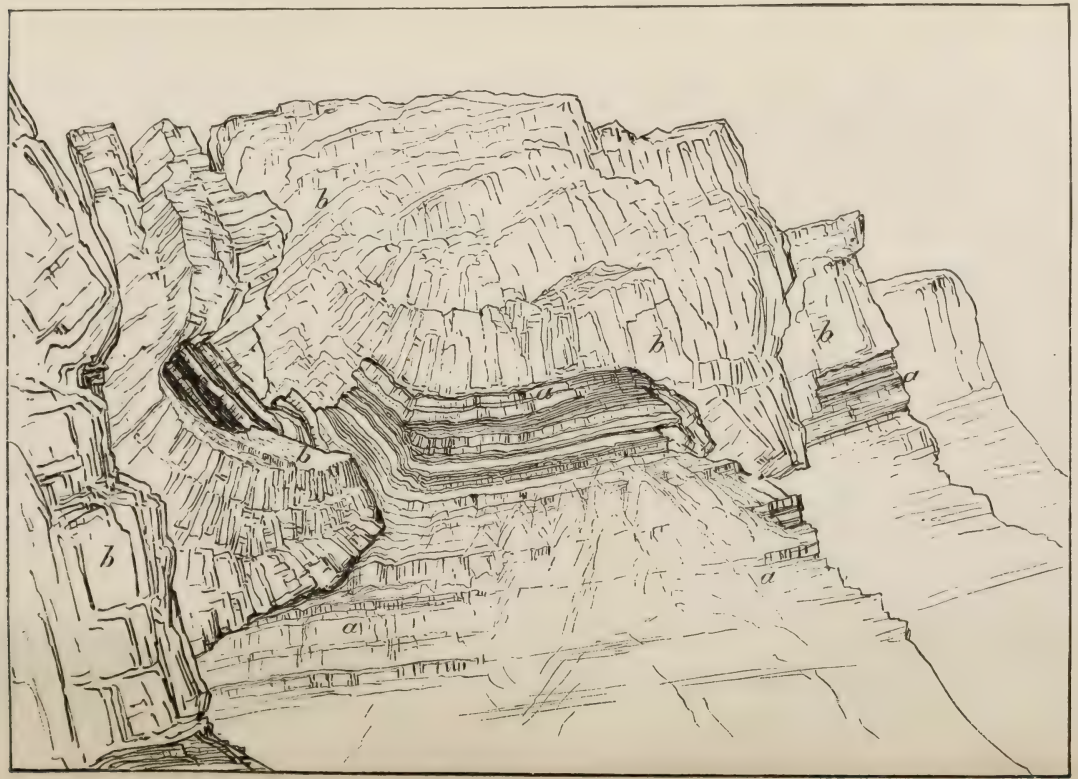
North from the point at which the rhyolite terminates, the outline of the mountain sweeps down in a bold curve toward the Yellowstone. There is no longer a capping of lava to sustain the sharply escarped edge, but a series of remarkable sheets of dark basaltic lava perform that office. Unlike the rhyolite, which has been flowed as a sheet upon the surface of the Cretaceous strata, these basaltic masses are included between the yielding strata, and if examined carefully may be seen to cross from horizon to horizon, breaking through the beds and pushing them aside, and bending and crushing them in a most remarkable manner. Down on the slopes to the north other masses of intruded rock are exposed, and beyond these the whole wall becomes so broken down and smooth that a horseman can ascend with ease. Down by the river a secondary wall occurs, and this, with an opposing wall on the west side, forms a little cañon through which the river flows. These strata, together with all those visible in the great wall, are Cretaceous. The dips all along are from 5 to 15 degrees to the north as seen from the west side of the river. There is also a dip to the east from the brink of the wall still more marked, and a very little beyond the crest the strata come within the influence of the abrupt fold of the great displacement which passes from northwest to southeast through the mass of the mountain. The dip, as we approach the axis of the fold, becomes vertical, and in places passes beyond 90°. The strata composing the upper half of the great wall are chiefly sandstones, generally rather soft, grayish and yellowish in color. Interbedded with the sandstones are shales, clays, and lignites. The lower part of the slope consists of dark-gray shales, beneath which, in the creek bed, are the sandstones of the Dakota Group.

On the 12th of September our party set out on its second trip, the march of the day being from the springs to Junction Valley. Wishing to see as much of Mount Evarts as possible, I determined to climb the wall at the first accessible point toward the north, visit the basaltic outcrops, and cross the flat summit of the mountain to the mouth of Black-tail-deer Creek. Riding down the steep slopes over the old hot-spring deposits and Cretaceous shales, I crossed the river about a mile below the springs, and led my mule up the long, steep, and cliff-broken slope. Along the river there is a broad belt of sloping ground that forms a sort of talus to the wall; this space is covered with sage and short grass, and is deeply cut by a multitude of narrow gulches which have been scored out by avalanches from the steeper walls above.

In the cliffs, from the base to the summits, the rocks which form the principal outcrop are fine-grained, yellowish sandstones, often quite massive.

There are numerous beds of sandy shales, and not infrequently intercalated lamina of quartzitic sandstone. At the base some of the falling masses contain indistinct impressions of deciduous leaves, together with imperfectly preserved fruits and irregular masses of carbonaceous matter.

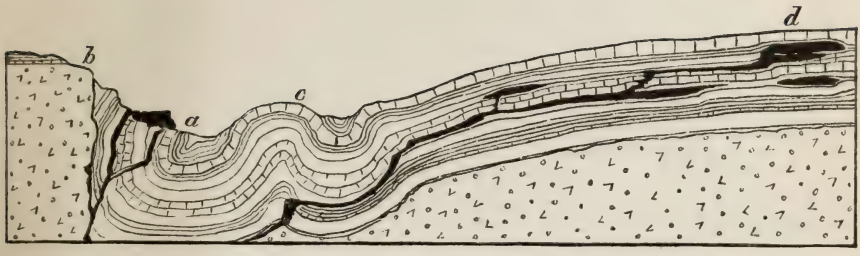
Throughout the section there are occasional indications of coal, which is apparently an impure shaly lignite. The exposures are, however, far from satisfactory. Outcrops of basalt occur, but are obscured by *débris*.



a a Cretaceous Coal Measures.

b b Basalts.

Plate V.—Intruded basalts, Mount Evarts.



Ideal section, showing the intruded basalts of Mount Evarts.

a Yellowstone River. *b* Fault. *c* Crumpled strata. *d* Mount Evarts ridge and basaltic masses.

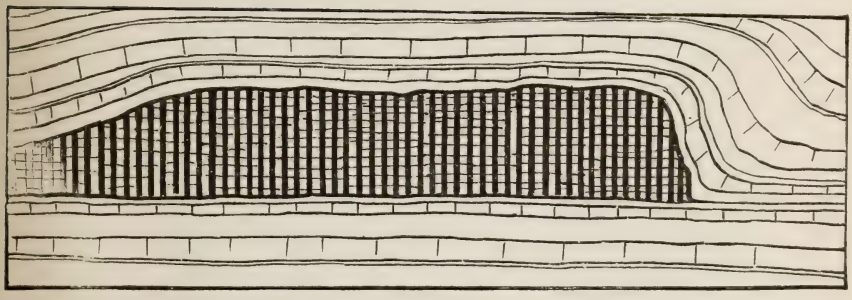


Plate VI.—Intruded basalts, Mount Evarts.

A sparse growth of stunted pines has taken root in the rocky slope and on the crest of the ridge there are groves of full-grown trees.

The examination of the basalts near the summit proved unexpectedly interesting. The masses of this rock are very irregular in thickness, reaching in places 40 and 50 feet, their position in the strata, being very irregular. They lie in rude sheets approximately with the strata, but bearing the strongest evidence of their intrusive character.

The irregular bed that outcrops along the crest of the ridge is in places 40 feet in thickness, but generally falls far short of this. Its position in the strata points very clearly to its intrusive character. It does not lie in any one horizon, but breaks across the strata at all angles, crushing the severed edges back upon themselves as shown in the drawing, Plate V. It rests chiefly in a series of coal shales and sandstones in which are very numerous leaf impressions. The shales are but little changed by contact with the basalt, and where in actual contact are still brittle and crumble under the hammer. The shales above the intruded mass are also but little altered.

In the heavier masses this basalt has a rudely columnar structure and weathers down in very small angular blocks. In the thin tongues that have been thrust out from the main mass into the surrounding strata there is a tendency to form small prisms at right angles to the surface, as shown in the figure; while the interior part of these tongues has only a minute irregular jointage.

The color of this basalt is, in the weathered surfaces a rusty brown, but when freshly fractured a dark steel gray. It is fine grained and compact and has no crystals distinguishable by the naked eye. The strata which inclose this basalt dip to the northeast at angles of from 10° to 15°, the line of the great fault, which defines their northern limit, being about two miles distant. It seems probable that the intruded basalts may have originated in or rather reached their present position through this fault, the crushing of the strata indicating, generally, an intrusion from that direction. Similar intrusions are very numerous in all the strata bordering the fault line. (See Plate VI.)

It may be well in this connection to give another illustration of the intruded basalts which occurs also in the western face of Mount Evarts, but farther south and within a mile of the mouth of the East Fork of Gardiner River, and within about 400 feet of the bed of the main Gardiner. The rock is a pinkish-gray basalt (?) that weathers down in crumbling heaps, but where freshly exposed is an exceedingly compact and fine-grained rock. The mass is about 300 feet long by from 12 to 15 feet thick and appears in the face of a steep wall of dark shales and laminated sandstones. It has been forced in between the yielding strata, folding them up almost at right angles at the ends, as shown in the figure, Plate VI. There is a decided alteration in the contiguous strata; the shales and sandstones for a number of feet beyond the contact with the intruded mass being changed to hard slates and quartzites which break up in minute blocks. Other intrusions occur all along the face of the wall that overlooks the cañons of the East Fork and are especially numerous about the falls and on the south side of the valley.

Having followed the crest of the mountain south from the previously described outcrops of basalt, I soon reached the north edge of the great sheet of rhyolite that rests upon the flat part of the summit. The northern border of this sheet is pretty thoroughly obscured by soil and drift deposits, and cannot be defined with accuracy, but the exposure on the west front is simply perfect. The whole thickness of the sheet, some 80 or 90 feet, breaks off in a vertical and overhanging cliff. The upper

surface is approximately level; the under surface takes the form of the depression into which it flowed, which, as shown by the section in the cliff face, had a gentle slope from the northern rim to the south. The sandstones dip in the opposite direction, that is, to the north, at an angle of about 15°. The ends of these strata had been planed down to a pretty uniform slope before the flow of the rhyolite occurred.

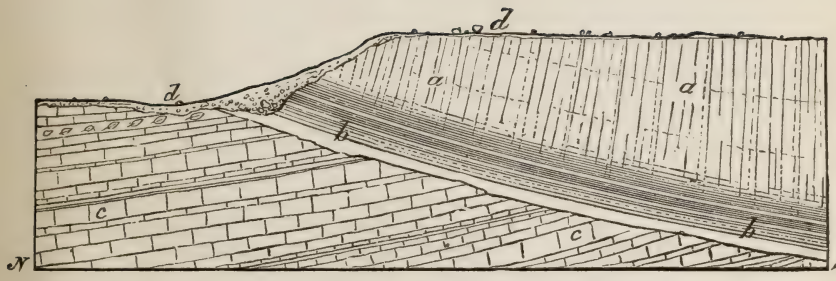
The most peculiar and interesting circumstance connected with this flow is the existence of a bed of loosely compacted material that lies between the sandstone floor and the sheet of rhyolite. This bed varies in thickness from 5 to 10 feet. The lower part is deposited upon the somewhat uneven surface of the sandstones, and is composed of a white powder that resembles slacked lime in appearance, and is probably a volcanic tufa. The white stratum runs up into a delicate gray stratum, which is succeeded by about 4 feet of fine grained laminated tufaceous sandstones that have the most perfect lines of bedding possible. There is an alternation of white, gray, and dark gray lines shown upon the smooth vertical surface that for perfection of line and delicacy of color could not be rivaled by the pencil of the skilled artist. That these lines indicate planes of bedding is clear, as there is a slight change in the coarseness of the material noticeable in the various layers. The most remarkable fact seems to me to be this, that these lines of color, as delicate as the finest penciling could make them, are continuous throughout the whole length of the wall examined. (Pl. VII.)

The whiter stratum at the base is not sufficiently compacted to allow the collection of a hand specimen. The grayer layers above have the consistency of a soft argillaceous sandstone, but have a very low specific gravity. Between the gray laminated layers and the base of the rhyolites is a zone of peculiar rock that seems to show an imperceptible transition from the one to the other. It is quite impossible to tell just where the rock ceases to be an aggregation of grains and becomes a true crystalline lava. This transition rock is dark in color, as is also the lower part of the sheet of rhyolite, and at a little distance looks very much like a basalt. Its weight, however, is not half that of an ordinary basalt, and when examined closely apparently consists of dark and light glossy grains imbedded in a paste of fine gray ash. The coarser lamina below contain a great deal of more or less finely pulverized sanidin.

In studying the delicate lamination of these tufaceous deposits one is led to inquire what could have been the method of their deposition. That they are not sub-aerial is evident, for it would be necessary to suppose the entire absence of all winds, as the least irregularity of deposit would destroy the continuity of the laminæ. It seems more probable that the almost impalpable dust from distant vents has been cast by the winds on the surface of deep and quiet waters and been allowed to settle on the bottom beneath. And yet with this explanation it is almost incredible that as much as ten feet of such delicate strata could be laid down without including a single particle above the size of a pinhead or without the intrusion of any form of organic body whatever.

The tufaceous stratum slopes at first about 16°, and further south, if it continues beneath the rhyolite, becomes horizontal. At the point examined it has been weathered out to the depth of several feet, allowing the rhyolite ledge to overhang. Similar and still more interesting deposits underlie the rhyolites of the grand cañon of the Yellowstone, and will be described in the proper place.

The rhyolite of the overlying sheet is quite dark, and by those who have seen it at a distance has been called basalt. It is a dark purplish-gray rhyolite of moderate weight, and is No. 2 in Captain Dutton's



a Sheet of rhyolite. *b* Finely laminated tufa. *c* Cretaceous sandstones. *d* Drift.

Plate VII.—Showing contact of rhyolite cap of Mount Evarts with the Cretaceous sandstones.

catalogue. It has a tendency to weather in rude columns, but these are not clearly defined. It doubtless forms a part of the great rhyolitic sheet, the borders of which can be found at a similar level all around the rim of the valley of Gardiner River, and which appears elsewhere further east.

The edges of the sandstone strata which come in contact with the white tufaceous stratum are somewhat discolored as if by metamorphism or oxydization of minerals. The section of these strata as given farther on extends from this point directly down the face of the cliffs, reaching Gardiner River at the base of the Mammoth Hot Springs.

On the 13th of August we had been forced by continued snow-storms to relinquish work in the Gallatin Mountains, and arrived at the springs preparatory to starting for Bozeman. On the 14th, accompanied by Dr. Peale, who had just arrived from the Geyser Basin, I determined, notwithstanding the fact that the snow was three or four inches deep, to examine the strata in the great wall of Mount Evarts.

Descending to the river, we passed over, as on a previous occasion, extended bodies of hot-spring deposits, beneath which, near the river, a limited outcrop of sandstones occur. These sandstones probably belong to the Dakota Group of the Cretaceous, and consist of 20 to 30 feet in thickness of massive, coarse-grained sandstones that dip beneath the bed of the river at an angle of about 15°. It is probable that these sandstones underlie a greater part of the drift and sinter-covered slopes of the west side of the valley. Beneath the massive bed of sandstone some laminated beds appear, which doubtless belong also to the Cretaceous.

Crossing the river, we rode for a considerable distance up the gorge-cut talus slope, which is covered with grass and sage. We hitched our animals, as far up as they could be taken, at the height of nearly 1,000 feet above the river bed, just opposite a steep cliff which overhangs a deep gulch. In the vertical part of the cliff are exposed about 200 feet of light-gray argillaceous and sandy shales.

From the base of the vertical cliff we climbed, not without considerable difficulty, as a snow-storm was raging, to the summit of the mountain at the northern end of the rhyolite escarpment. Rather imperfect impressions of leaves were found at a number of localities. Professor Lesquereux having examined them, announces that they certainly indicate the Cretaceous age of the formation. A small number of rather imperfect fossil shells were found near the top, which are considered by Professor White to represent Upper Cretaceous, and possibly Post-Cretaceous species.

The section, beginning at the top, is as follows:

	Feet.
1. Drift.	
2. Purplish sanidine trachyte	80
3. Stratified tufaceous sandstones	8
4. Sandstones, alternating with clay, sand, and carbonaceous shales. Near the upper part are some layers of flinty concretionary limestone. Beneath these and just under the ends of the rhyolite bed is a leaf-bearing stratum of sandstone, containing the following species: *Sequoia Richenbachi*, *S. fastigiata*, *S. subulata*, *Andromeda Parlatori*, *Bonmetia Marconana*, a proteoides and fragments of conifers. The sandstones contain many irregular and oval masses of clayey and carbonaceous matter, and also masses of wood	60
5. Sandstones, sand shales, clays, and lignitic clays. The softer strata predominate. The beds of sandstone are seldom more than 4 feet thick. Near the base of this group a number of the fallen fragments of sandstone were found, in which were imbedded the following fossils, all of which are in a very poor state of preservation: *Corbula* (?), *Viviperous* (?), *Goniabasis* (?), *Ostrea* (?)	225
6. Carbonaceous shales and lignites. Some of the seams of lignite are upwards of 10 feet in thickness, but contain much fire clay and other impurities	40

	Feet.
7. Pretty firm sandstone, with occasional pockets of lignite and carbonaceous clay. Some obscure impressions of leaves and shells	160
8. Sandstone, alternating with sand shales, lignitic seams, and clays. First prominent outcrop in ascending from the river	300
9. Gray, dark gray, and blackish sandy shales, in places much indurated, and, where in contact with intruded basalts, quartzitic. These form the lower part of the wall and reach to the river bed. They are much obscured by *débris*. These strata all dip at angles varying from 8° to 15° to the north or north-northeast	900

In the shales beneath the intruded mass of basalt, shown in Plate VII, there are numerous but rather obscure impressions of fish scales.

The lignites which occur so plentifully in the strata of this mountain are generally of a very inferior quality, and if we are to judge from the surface indications will probably never be available for economic purposes.

Along the banks of the Gardiner, below the junction of the East Fork, there are outcrops of Cretaceous shales that indicate some local disturbance by which they have been tipped up at pretty high angles. These disturbances are probably owing to the intrusion of masses of basalt rather than to any general movement.

Mount Evarts is separated from the high plateau region south of the forks of Gardiner River by the deep valley of the East Fork. The strata, however, are continuous, and will be found to correspond on the opposite sides of the valley. On the south side they are much obscured by the loose *debris* of land slides, and soon disappear entirely beneath the broad sheets of rhyolite that form the surface of the southern plateaus. The basaltic intrusions are very numerous, and at the falls of the East Fork heavy masses of dark columnar basalt occur. The sheet of rhyolite overlies these basalts at the falls and is weathered back from the brink of the cliffs at the north. The flat region that extends from the East Fork above the falls eastward toward Junction Valley, as well as the greater part of the flat summit of Mount Evarts, is covered with coarse drift which consists greatly of granitic material.

Between the front ridge of Mount Evarts and the group of hills—mentioned in describing the Yellowstone displacement—which form the extreme northeastern portion of the mountain, we have a gently undulating country which possesses much pastoral beauty. Groves of pines and aspens dot the broad expanse of rich grass land, and numerous ponds and lakes occupy the depressions between the low hills and ridges.

I found two of the higher summits of the group of hills just mentioned capped with rhyolite, similar in every respect to that which forms the broad summit of the main mountain. Beneath this rhyolite on the northern side of the hills are some slight outcrops of horizontal strata that apparently belong to the later Tertiary. On a subordinate butte to the north these strata contain a number of stumps of silicified trees, which rise through the inclosing sandstones and conglomerates, and stand a few feet in height. There are also some basaltic layers in these strata. Beneath on all sides are the stratified schists. The river runs in a deep, narrow cañon in these rocks, upwards of 2,000 feet below the summit of the hills. North of the river the rugged slopes are composed entirely of the schistose rocks. The strike of these rocks is north some 40° or 50° E., and the dip always to the southeast at a high angle.

In descending to the valley of Black-tail-deer Creek, I passed down over the schistose strata and on the opposite side soon reached a region covered with basalts. The valley of Black-tail-deer Creek has but slight exposures of strata. A heavy sheet of drift, probably both river

and glacial, covers the whole face of the country for a number of miles east of Mount Evarts. Down toward the cañon of the Yellowstone ledges of columnar basalt outcrop along the deep gulches.

SEPULCHRE MOUNTAIN.

Why this mountain received such a melancholy appellation I have not been able to discover. So far as I know it, the most important thing buried beneath its dark mass is the secret of its structure. It is possible that the form has suggested the name. In shape it is a rudely rectangular mass with pretty even and rather gentle slopes below, and steep walls above, which culminate in an elongated and flattened crest. Topographically it is almost isolated. The north base is washed by the Yellowstone River, the east by Gardiner River, the west by Cache Creek, and the south by the West Gardiner. Geologically, also, it stands alone. It is a mountain, built up of recent volcanic ejecta, in a broad depressed space between two sedimentary mountains, Mount Evarts and Electric Peak.

The former has a great wall, facing Sepulchre Mountain, on the east, composed of Cretaceous strata which dip to the north at a gentle angle. The latter has a similar wall which overlooks it on the west side. To all appearances these strata originally connected across, having doubtless a uniform slope toward the line of the Yellowstone fault. What causes conspired to plane down the space between these walls I know not, but that such a planing down occurred, and that subsequent volcanic ejecta built up a mountain on the depressed space, are patent facts.

On the occasion of each of my visits to the summit of Mount Evarts the weather was such as to prevent the sketching of the east face of Sepulchre Mountain. On the first visit the broad, undulating slope that rises gradually from Gardiner River toward the steeper crest could be indistinctly made out, and the white and parti-colored mass of the Mammoth Hot Springs appeared like a fragment of a glacier in the midst of the mountain. Forest and pasture lands occupy nearly equal portions of the surface, and the exposures of geologic formations are infrequent save toward the summit. The greater part of the whole surface has a remarkably perplexing topography, the hot-spring deposits and the very numerous land slides having produced thousands of depressions and elevations that are totally without system in their arrangement.

There is a very general distribution of drift material over the lower slopes, the origin of which is rather puzzling. As high up as the springs, and even to the divide that separates the upper valley of the West Fork from the main valley below, there are remnants of drift-covered terraces. Some of these steps are the result of hot-spring deposits, but others are undoubtedly due to the action of water or ice.

The great trough-like valley of the Gardiner is undoubtedly due to erosion, and has probably been of rapid formation, since as soon as the river had penetrated the sheet of rhyolite upon which it was first superimposed, and the firmer strata of the Upper Cretaceous formations, the cutting would necessarily be very rapid through the less compact formations of the Middle Cretaceous, and what is more, by a process of undermining, the valley being monoclinal, the bed of the stream would descend with the dip of the rocks, and hence have a tendency to move from the west to the east. The whole series of flood planes would naturally be left unchanged on the west side, excepting as they happened to be destroyed by the very meager lateral drainage or by slides.

The drift materials are composed mostly of the rounded fragments of such rocks as occur in the valley above and on the sides of the neighboring mountain.

On all parts of the slope, especially about the springs, there are very numerous erratic fragments of indurated calcareous sinter that resembles very closely an ordinary limestone. They are yellowish, compact masses, with rough, scoreaceous-looking surfaces, and it was not until I had made several attempts to find fossils in them that I discovered that they were of hot-spring formation, and that they had their origin in a heavy stratum that occurs on the summit of a flat-topped hill that overlooks the cañon of the West Gardiner, and is separated from Sepulchre Mountain by the depression through which the road passes.

The drift, slide and hot-spring material that covers the greater part of these slopes is underlaid by Lower Cretaceous and Jurassic rocks, which rise from the bed of the river at the base of Mount Evarts with a dip that corresponds approximately with the slope. They soon pass beneath the rhyolites and conglomerates that constitute the upper part of the mountain, excepting in the vicinity of the pass which leads from the spring over the ridge south into the upper valley of the Gardiner. Here the volcanic rocks have been eroded away and a small area of Jurassic rocks is exposed.

On the 10th of September I left camp at the springs and passed up the drift-covered ridge to the north of the deep gorge at the mouth of which McCartney's cabin is built. Snow had fallen to the depth of three or four inches the night before and the day was cold. In the drift there are fragments of basalt, quartzite, flinty limestone, and a peculiar coarse conglomerate. The latter is doubtless derived from the breaking down of the conglomerates of the Dakota Group, which outcrops in the steeper parts of the gulches about the springs. About half a mile above McCartney's house there are a few ledges of hard calcareous sandstone which appear above the coarse avalanche *débris* and the heavy deposits of vegetable mold. This sandstone I take to be Cretaceous also. Just here occurs a good illustration of the movements that have produced the irregular topography of this locality. A large mass of rocks and earth has been detached from the steeper slopes above by excessive moisture and has been precipitated into the bed of the rivulet, which has thus been turned out of its course to find its way across the terrace to the north into another deep gulch.

Turning to the left I soon found myself at the top of a steep bluff which overlooks the "Grotto in the glen," a hot-spring mound formed by one of the highest of the living springs. In the face of the bluff I came upon an outcrop of hard calcareous sandstone strata in which there are imperfectly preserved Jurassic fossils. The exposed strata have a thickness of about 40 feet. The dip is to the northeast, at an angle of about 40°. Beyond this, in the cliff that borders the wagon-road-pass on the north, the same rocks outcrop and have nearly the same dip and strike. In the road a stratum of dark shales or slates has been exposed, in which are two or three varieties of Jurassic fossils. In the cliffs above there are about 500 feet of strata exposed, which includes yellowish quartzitic and calcareous sandstones, and toward the top shales and shaly sandstones. In the harder strata a few fossils were found, including species of *Rhynconella*, *Campronectes*, and a *Penticrinus*. The less compact strata above contain occasional seams of flinty limestone. There is much selenite and a little carbonaceous matter. The shales show some ripple marks. In the slide rocks there are fragments of conglomerate, like that seen at the springs, which contain

bits of limestones and other sedimentary rocks. We have here the highest outcrop of the pre-Tertiary strata that occur in this mountain. The cliffs are capped by about 200 feet of gray and reddish-gray rhyolite. The base of these rhyolites is at an elevation of 8,000 feet. This elevation corresponds to the base of the great sheet of rhyolite that occurs on Mount Evarts, and seems to indicate a former connection across the valley of Gardiner River. Mineralogically the rocks are identical.

The long flat ridge that lies between the wagon-road pass and the cañon of the West Gardiner is capped by a sheet of hot-spring limestone. This, however, is underlaid by rhyolite. In the pass we have exposures of the Jurassic rocks, but just beyond the rhyolites descend to the bottom of the little valley that drains the western side. They may be followed for a short distance along the base of the slopes to the right and left of the road. A low ridge of dark rock reaches down to the road from the left, and one at first sight is led to believe that here is a mass of basalt, but on closer examination it is found to consist of a dark pitchstone with large crystals of sanidin; a rock similar to that found forming the under surface of most of the rhyolite flows in this region.

The peculiar topography of the little gorge or pass through which the road is built leads us to inquire of its origin. It is not at all improbable that at one time it has been occupied by a stream of water, which, by some local change, has been turned into another channel. The highest part of the pass is composed of a loose mass of fallen rock and earth. The bed of the channel of the supposed old stream may have been choked up by such falling masses, or even hot-spring deposits, which are so plentiful in the vicinity, may have assisted in the change. There are also some fragments of basalt and of drift material, which indicate that this was a passage for water some time in the past. The courses of the little streams that head about the west slopes of Sepulchre Mountain are rather eccentric, and suggest the probability of their change by some local cause from their original courses. The valleys that lie about the west slopes of Sepulchre Mountain are covered with drift materials and soil, and contain large areas of fine pasture lands. About the immediate bases of the mountain there is a good deal of pine timber.

From the pass I turned to the right and ascended the sharp spur of the mountain that overlooks the springs. The rhyolites (No. 1, Captain Dutton's catalogue) soon disappeared, and were succeeded by a dark, coarse basaltic breccia. Masses of dark, fine-grained basalt, as much as 3 or 4 feet in diameter, are mingled with the finer materials, which are also basaltic, although of a great variety of colors and textures. I did not attempt to reach the summit of the mountain on account of the snow, but feel assured that the breccias and conglomerates constitute the bulk of the mountain from this point up. In descending to the north I soon reached a shelf-like space, the floor of which was composed of the usual rhyolite. This is at a level corresponding pretty closely to that of the other occurrences of similar rock about the rim of the valley.

Between the rhyolite ledge and the springs the steep slopes are clogged with fallen materials. By the yielding of the softer rocks beneath, large masses of the rhyolite become detached and gradually sink into the deep amphitheaters beneath.

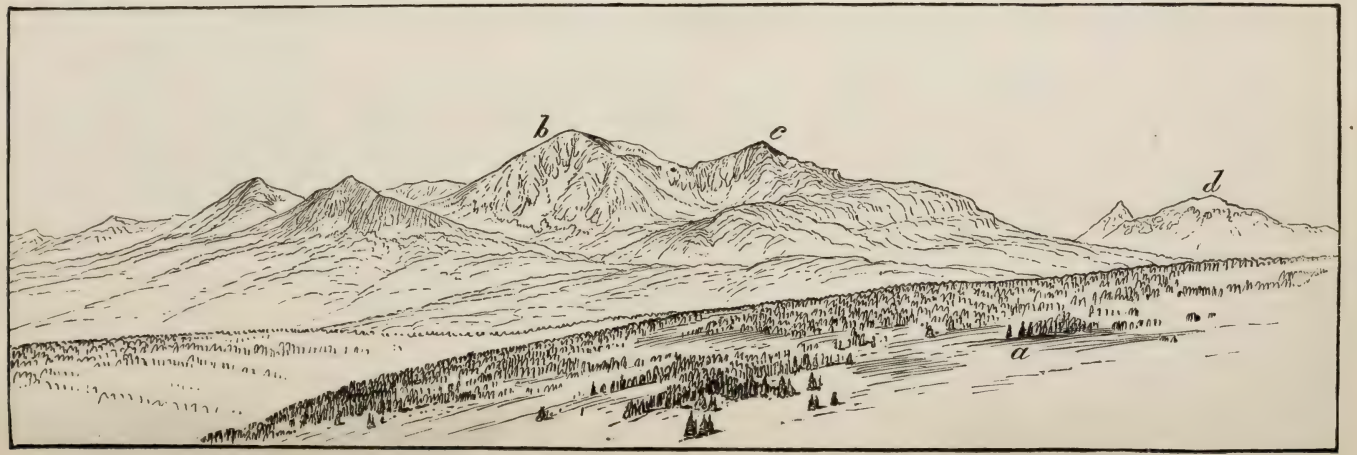
About 500 feet below the outcrop of rhyolite a heavy mass of hornblende trachyte makes its appearance through the *débris*. Its relations to other rocks cannot be ascertained. It weathers into round massive forms above, but below breaks up into angular fragments. It is hard and heavy and yellowish gray in color, and contains numerous large

crystals of hornblende. In general appearance it is much like the hornblende trachytes of southwestern Colorado. Similar rocks occur largely in the Mesozoic and Paleozoic rocks in the Gallatin Range, 10 miles to the west of this point. It is quite probable that this mass is part of a sheet interbedded with Cretaceous rocks, which from its greater hardness has resisted the erosive forces.

On the day following I rode around Sepulchre Mountain to the north, crossing, for the first mile, smooth, grass-covered slopes, over which are scattered numerous fragments of hot-spring limestone and other rocks. A little beyond the first rivulet there is a low hill, capped with basaltic breccia, and beyond this on the opposite side of a second stream another hill or butte, much larger than the first, which is also formed of the basaltic breccia. In the depression between these hills there are a number of small lakes or ponds, which seem to occupy depressions formed by masses of conglomerate that have slid down the slopes and intercepted the streams. It appears that the whole slope from the base of the massive walls of conglomerates above down to the wagon road, and even in places to the river, is covered with masses of the breccias and conglomerates that have come down from the summit of the mountain.

Farther around to the north, directly under the high walls of the main summit, this degradation by land slides has taken place on a grand scale, and the same agencies are still actively at work. Many of the larger spurs and outstanding masses are nothing more than sinking fragments of the conglomerates. Great terrace-like masses of conglomerates have detached themselves from the main mass above, and still remain but little depressed, but are separated from the present mass by deep crevices. Some of these masses have progressed still further and are beginning to break up into blocks. The forest trees that cover these masses present a very extraordinary appearance, as they are tipped about at all angles. To one who did not understand the causes of these movements the region would present the appearance of having been subject to violent volcanic action, or to the movements of an earthquake. The occurrence of these gigantic slides is easily accounted for. The heavy, coarsely bedded, and rather compact conglomerates of the upper part of the mountain are everywhere underlaid by a series of fine-grained uncompacted material, chiefly marls, sand, and shales. In moist seasons this soft rock gives way, and rapid degradation is the direct consequence. Much of the drift material in the surrounding valley is derived from the disintegrated conglomerates.

Along the lower slope of the mountain, on the north side, there is a band of light-colored marls that seems to underlie the conglomerates and to rest unconformably upon the Cretaceous strata beneath. In the great northern spur, that extends down to the river at the mouth of Cache Creek, strata, apparently corresponding to the marls, lie beneath the massive conglomerates that form the crest of the ridge. These strata are light in color but generally coarse grained, and are composed of a variety of materials that comprise all kinds of rocks from white volcanic tuffs to masses of feldspathic granite. I did not have time to observe these strata carefully, and hence am in much doubt in regard to them. They are apparently quite modern, and it is not improbable that they are Pliocene lake deposits, as the conglomerates, which overlie them, are not probably later than late Pliocene, and these beds were evidently deposited in a body of water that existed at the beginning of the conglomerate building period. On the north side of the point of the spur mentioned above a mass of hornblendic trachyte occurs, very similar in appearance to that found above the springs. It is not probable



a Madison Plateau. *b* Mount Holmes. *c* Trilobite Point. *d* Sepulchre Mountain.

Plate VIII.—Southern end of Gallatin Range.

that this rock belongs in the conglomerates. In all other cases it appears in connection with the older strata.

EAST GALLATIN MOUNTAINS.

The range known by this name forms one of the most striking topographical features of the Park. Heretofore but little has been known of its character or extent, and its geological structure was entirely unknown. From nearly all parts of the Park its higher summits are distinctly visible. At the southern extremity is a naked, yellowish summit (see sketch, Plate VIII), which is particularly conspicuous, and is plainly visible from nearly all the flat country about the Madison Geyser Basins; while at the northern extremity Electric Peak lifts its pyramidal crest far above its fellows. The distance between these peaks is about fifteen miles. At the extreme northern end the range terminates in Cinnabar Mountain.

The continuation of this range to the westward and its connection with the main Gallatin Range are not well known. It is composed almost wholly of sedimentary rocks, the main range being chiefly volcanic. It has a decided north and south trend and is separated from the main range by low passes. Its western slopes are drained chiefly by the headwaters of the Gallatin River, and by the two large creeks that enter the Yellowstone in the vicinity of the second cañon. The eastern face is drained by Cache Creek and Gardiner River.

The eastern and southern faces of the range are very abrupt and present a very good section of the formations. The strata rise at a gentle angle from the line of the Yellowstone fault at Cinnabar Mountain and probably retain pretty nearly the position given them at the time of the post-Cretaceous displacements.

Beginning at Cinnabar Mountain and passing along the eastern base of the range we find that group after group of the geologic series rise from the level of the Park plateau and pass to the summits. At the southern end of the range the granites appear in a crescent-shaped exposure.

There is at present no apparent reason for supposing that at the close of the post-Cretaceous disturbance the whole series of formations was not continuous to the east and west of this range. To the east we have in Mount Evarts proof of continuation in that direction; however this may have been, it is quite clear that at the time of the flooding of the Park region with its great sheets of igneous matter, the eastern and southern faces of this range rose as abruptly along the borders of the great basin as now. In this basin the igneous matter was poured, and at the end of the period of the rhyolitic flows a great undulating plateau was formed, which, around the bases of this ancient fragment, had a general elevation of about 9,000 feet.

In Plate IX, I present a panoramic view of this range as seen from the southeast, looking across twenty miles of the igneous plateau. In the foreground we have the newly-discovered Gibbon Geyser Basin with its surrounding of dense forests. At the left is Mount Holmes, with its smooth conical summit, surrounded by a number of subordinate cones. At the south base, rising about 800 feet above the general level, are the Archaen granites; above this and extending to the summit is a heavy series of Silurian strata into which have been intruded great sheets and laccolitic masses of compact hornblendic trachyte. The dip of the Silurian strata is to the north at a gentle angle, as may be seen in the drawing.

Electric Peak may be seen in the distance to the right, and presents two main summits, the eastern one being higher and sharper than the western. The strata of this mountain are wholly Cretaceous, and dip also to the north at gentle angles. Between Mount Holmes and Electric Peak we have a pretty good view of the great eastern wall of the range, deeply cut at irregular intervals by four great valleys or cañons which drain to the east into Gardiner River. In the steep walls of each of these cañons we have fine sections of the strata composing the wall. In the first massive spur to the north of Mount Holmes the Silurian strata have been disturbed by intrusions of immense masses of hornblendic trachyte, which appear between the limestone strata where the latter are horizontal, and also in the high point to the left, where they have been pushed up through the strata.

Next to this ridge on the north is the valley of Indian Creek; beyond this is a steep, almost vertical wall, in which some interesting features appear. At the base is a massive ledge of Silurian limestone, which weathers in vertical lines, as seen in the drawing. Lying on the upper surface of the limestones is a mass of hornblendic trachyte (see Plate XIII), which has been intruded between the limestones and the overlying strata, arching the latter in a manner similar to the hornblendic trachytes of southwestern Colorado and southeastern Utah. The Carboniferous strata form the upper part of the wall.

Beyond the next valley is a very broad, massive spur, formed almost entirely of Carboniferous strata. The dip is uniformly to the north, as may be seen by reference to the drawing. The valley between this spur and Electric Peak is very broad, and the crest of the range, along which all the spurs unite, is pushed far back to the west by the strong drainage of this valley. To the east of Electric Peak we have Sepulchre Mountain, the western face of which is seen. Beyond, through the saddle which connects these two peaks, the crests of the Yellowstone Range may be seen.

Such geologic details as I have collected in my brief visits to the East Gallatin Range will be presented in the order in which they were observed.

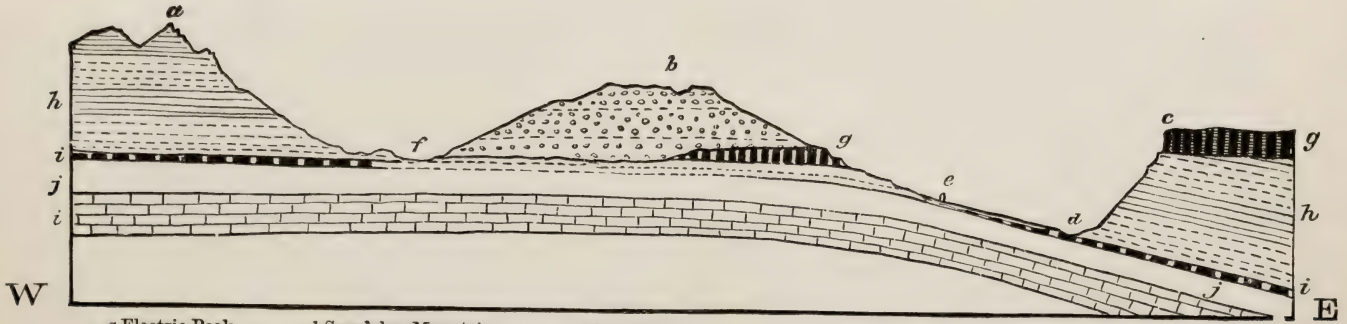
While encamped at the springs during our first visit, Mr. Gannett determined to visit Electric Peak for topographical purposes, and I concluded to keep him company, and make such observations of the geology as my limited time would allow.

On the morning of the 12th of September we left the springs at sunrise, and, not being acquainted with the shorter route to the west of Sepulchre Mountain, set out by the way of the wagon road and Cache Creek. Having ascended the open valley of Cache Creek for about a mile, we turned to the right up a very steep, grass-covered spur, that leads up to the ridge which connects Cinnabar Mountain with Electric Peak. On our left was the steep wall that surrounds the head of Cache Creek, and above us, to the south, the rugged cliffs of Electric Peak. The Cretaceous strata, which at the base of Cinnabar Mountain are so crumpled and broken, are here but slightly disturbed, and rise with a gentle slope to the south. On the opposite side of Cache Creek the northern spur of Sepulchre Mountain presents a steep, partially forest-covered wall; in this a series of heavily bedded volcanic conglomerates appear.

We found the flatter parts of the northern slope of Electric Peak to be covered with snow to such a depth as to make progress in places quite difficult. We were able, however, to take our animals to within a few hundred feet of the summit. The strata are wholly Cretaceous,

a Mount Holmes. *b* Trilobite Point. *c* Valley of Indian Creek. *d* Bell's Peak. *e* The Great Laccolite.
f Quadrant Mountain. *g* Electric Peak. *h* Valley of Gardiner's River.

Plate IX.—General view of the East Gallatin Range from Gibbon Geyser Basin.



a Electric Peak. *b* Sepulchre Mountain. *c* Mount Evarts. *d* Gardiner's River. *e* Mammoth Hot Springs.
f Head of Cache Creek. *g* Sheet of rhyolite. *h* Cretaceous shales. *i* Dakota group. *j* Jurassic strata.

Plate X.—Section through Electric Peak, Sepulchre Mountain, and Mount Evarts.

although apparently not fossiliferous. They consist of shales, slates, and indurated sandstones. Our animals were left at the base of the western summit, which presents to the north a smooth but steep *debris*-covered slope. We passed around the left face of this summit into a low saddle, and thence up to the sharp crest of the higher eastern summit.

All the strata of the upper part of the mountain are highly metamorphosed, and the slates and quartzitic sandstones present some remarkable examples of jointage. The jointage planes are well marked and very persistent, but have such a variety of directions that it was impossible for me to make out their exact relations to the directions of the dips and strikes. One had but to strike a mass of the rock to make it fall into a hundred angular blocks with faces as true and angles as sharp as if they had been dressed by a joiner. The eastern summit is very rugged and the sides extremely precipitous. A broken spur extends to the north and overlooks the valley of Cache Creek; another extends to the east and connects with Sepulchre Mountain by a low saddle, through which there is a pass from the head of Cache Creek to the valley of the Upper Gardiner. The height of the summit above the sea is 12,000 feet. The western summit is about 50 feet lower. The dip of the strata is to the north and varies from 10° to 20°. The cause of the metamorphism is not very evident; the intrusion of very numerous dikes of igneous rocks has at least contributed to the hardening of the strata. The northern spur has been penetrated by a very complicated system of dikes. Its western face is tattooed by countless dark-brown lines and patches, which are probably mineral-bearing dikes of hornblendic trachyte. The specimens of this rock collected do not differ greatly from the hornblendic trachytes that occur throughout the whole series of pre-Tertiary rocks.

This peak, being the highest within the Park, gives a very comprehensive view of the greater part of this wonderful region. The lake alone is not visible, the bulky mass of the Washburne Range and the Elephant's Back Plateau effectually hiding it. Beyond, however, can be seen the Upper Yellowstone Mountains, the Red Mountain Range, and far beyond this the Teton and Wind River Mountains, with their snowy uplands and serrated summits outlined against the horizon. In the broad intervening space we look down upon the black forests of the Geyser Region, which are partially relieved of their gloom by a few yellow meadows and far-distant columns of steam. Immediately beneath us we have the lovely meadow country, drained by the various branches of Gardiner River. To the right of this and to the south we have the broad mass of the Gallatin Range, which ends in the prominent dome-like summit at the south. The broad mass of the range, as viewed from this point, seems like a lofty plateau cut by a series of transverse valleys in such a way as to sever the range into four or five east and west ranges. The connecting ridge, the crest of the range, may be followed along the western border of the range, although its summits are not especially marked. On the west there is a pretty abrupt descent to the wooded country belonging to the drainage of the Gallatin River. Beyond the depressed belt rise the Madison Mountains with their many picturesque summits. To the left of these is the Henry's Lake Range, of which Sawtell's Peak forms the chief summit. In the middle distance are the broad meadows of the third valley of the Madison, and between that and Sawtell's Peak the well-known Tyghee Pass.

In looking down on the summits of the series of ridges that form the southern extension of the Gallatin Range, one is at a loss to detect their

geologic character farther than to perceive the fact that they are formed of sedimentary strata resembling the strata of which this peak is formed. We are looking down upon the backs of the strata which dip beneath us, and it is only in the walls of the broad amphitheaters facing us that outcropping beds can be seen, and the appearance of these does not assist us in determining their age. The broad summits of the ridges are snow-covered, and the slopes and upper valleys are also covered with dark fields of fallen rocks. The middle slopes have a pretty dense growth of pine forest, and the valleys lower down have parks and meadows. The southern face of the peak descends in a smooth but steep slope to the bed of the large creek which drains this part of the range, and which is without a doubt the main branch of Gardiner River. The view to the west is pretty nearly all cut off by the dark volcanic ridge that lies between Cinnabar and Cañon Creeks, tributaries of the Yellowstone.

The broad northern spur extends down to the Yellowstone and terminates in Cinnabar Mountain. On the left is the valley of Cinnabar Creek, and on the right Cache Creek. Beyond the valley of the Yellowstone is Dome Mountain, which overlooks the second cañon on the north, and beyond that Emigrant Peak lifts its noble summit above the neighboring mountains, while the snow-covered ranges that extend to the east through Delano Mountain and Helmet Peaks to the Rosebud and Clark's Fork Mountains present a magnificent panorama. Seven thousand feet below us, and seemingly almost beneath our feet, is the valley of the Yellowstone, the dark line of the river running like a thread through the yellow meadows. Rising from this to the north are steep grassy slopes, and, still higher, belts of dark timber, and far back, crowning all, a rim of countless summits that bewilder the eye and defy the utmost skill of the pencil.

The geologic structure of this grand mass of mountains remains a profound secret. The higher summits appear to be capped, at least, with the volcanic conglomerate, but even this is not certain. To the west of Emigrant Peak are the Mystic Lake and Blackmore Groups of the Gallatin Mountains, and to the north of these the Bridger and Crazy Woman Ranges. Turning to the east we find that the lower valley of Gardiner River is wholly hidden by Sepulchre Mountain. The upper part of the wall and the plateau-like summit of Mount Evarts are in plain view west, and a very good general view of the valley of the Yellowstone and of the ranges that border the East Fork can be had.

The stretch of broken, parked country bordering the Yellowstone and its tributaries is beautifully shown, and from the cold heights of this lofty mountain seems unusually attractive and full of sunlight. The scene to the north, as the blue shadows of evening fill the valleys and creep up toward the crests of the purple and golden ranges, makes us realize in its fullness that this is a land not only of the wonderful and beautiful, but pre-eminently of the sublime. As night approached we descended in great haste, and at a late hour reached camp at the springs. The section given in Plate X will make clear the relations of Electric Peak, Sepulchre Mountain, and Mount Evarts.

On the 2d of October we arrived at the spring the second time, having been driven in from the Yellowstone Mountains east of the lake by snow-storms. On the following day we set out for a few days exploration in the upper valley of Gardiner River, the Gibbon Fork geyser country, and the Gallatin Mountains. Late in the evening of the 7th we went into camp at the southeast base of the western slope of the Gallatin Range. The country about the base of the mountains around the south

Plate XI.—Volcanic conglomerates, showing style of weathering in West Gallatin Mountains.

end is flat or undulating and is covered by a dense pine forest. There are no exposures of rock until we rise above the general level of the plateau and encounter the granite. Alluvial drift, with probably more or less glacial drift, covers a large area all around the east and south bases.

On the morning of the 8th Mr. Gannett and I set out to ascend the southern summit of the range, which is only inferior in elevation to Electric Peak, being 10,100 feet in height. This peak, or what we suppose to be this peak, has been spoken of occasionally by visitors as Mount Madison, but on what authority or for what reason it is not known. Mr. Gannett having first ascended it and determined its height and geographic position, proposed to give it the name of the writer, and by that name it will appear on his maps.

At an elevation of 8,000 feet we emerged from the forest and came out into a parked zone that skirts the lower slopes. Here there are fine upland pastures to which the wild game of the country resorts. Herds of elk were frequently encountered, and the country is literally cut up by their trails. At an elevation of 8,700 feet we reached an outcrop of reddish feldspathic granite. This rock is very compact and massive, and forms a low rounded bench which may be traced around the base of the mountain, and which on the map will give a crescent-shaped area, circling the south base and separating the Silurian rocks of the range above from the drift zone that occupies the immediate base. Resting on the granite is a bed of about 200 feet in thickness of hornblendic trachyte, which has been intruded as a broad sheet between the granite and Paleozoic strata above. The ascent of a very steep declivity of some 500 feet brought us to the point of a narrow flat-topped promontory projecting to the southeast from the main peak. In the steep face of the promontory there are some 300 or 400 feet of dark gray laminated but much indurated limestones. They contain no recognizable fossils. These limestones form a well-marked escarpment that exends around the base of the range, sinking with a dip of 2° to 5° to the level of the drift plain on the south slope.

From the promontory we passed up over heavy snow fields and up a sharp crest, and at an elevation of 10,200 feet reached a sharp conical point, a southeast outlier of Mount Holmes. Between this point and the main summit there is a depression of a few hundred feet. The exposed strata are limestones, siliceous limestones, and quartzites, with a few seams of indurated trachyte. Between the granites and the summit the rocks exposed have a thickness of upwards of 1,500 feet. In the middle part of the section there is a pretty heavy series of fossiliferous limestones, from which I obtained two species of *Orthis*, *Heliolites* (*?*), *Lingulepis*, and *Trilobites*, the two latter occurring in great numbers. Good specimens are hard to obtain on account of the very firm texture of the rock.

There are occasionally beds of dark fetid limestone, and throughout the whole series more or less calcite in pockets. That the formations exposed in this mountain are chiefly Silurian is proved by the fossil remains, and that they are probably all of this age, from the granite to the summit of Mount Holmes, seems probable from the very uniform character of the strata.

The day being exceedingly cold I had to refrain from prolonged examination as well as from the usual sketching. Topographically the peak is simple, but scenically rather imposing, occupying, as it does, the extreme point of the range and overlooking a grand sweep of low country bordering the Madison. The sides of the mountain are comparatively

smooth. The limestone and quartzite strata, being rather thinly bedded, break down in small fragments which form into slides and fill up the uneven places. The drainage of the peak appears to be entirely tributary to the Gardiner River. Extending from the summit to the north, along the right side of Indian Creek, is a high, narrow ridge, which follows the course of Indian Creek as it turns to the east, and terminates in a high point, which in the drawing (Plate IX) forms the second ridge, the first being the eastern spur of Mount Holmes or the Trilobite Ridge.

The geology of this ridge, and of the crest of the divide which extends along the left bank of Indian Creek, I could only determine in a general way. The strata are chiefly Silurian, with probably a moderate thickness of Carboniferous rocks on the higher summits, and with very considerable bodies of intruded trachyte, which in its manner of occurrence resembles very closely the hornblendic trachytes of Southwest Colorado. The highest point on the northern spur of Mount Holmes is apparently formed of trachyte, which belongs to one of these intruded masses, and which has turned the Paleozoic strata up at pretty high angles around it.

South from Mount Holmes some 3 miles there is an outstanding mountain mass, which connects with the Gallatin Range just west of the former mountain. It lies between the headwaters of Obsidian Creek on the east and a northern branch of the Madison on the west. After descending from Mount Holmes I made an attempt to reach this point, but failed for want of time. The rocks so far as I went are granites. It is probable, however, that there are Silurian rocks on the higher points. Beyond this point there is a gradual descent to the Madison Plateau, of which such a fine section is seen in the third cañon. The outline view of Mount Holmes given in Plate VIII was made from the edge of Madison Plateau, opposite the mouth of Fire Hole Fork.

On the morning of the 9th I left camp at an early hour, and passed around the timbered base of Trilobite Spur to the north. The granite bench continues along the base of this spur, and is last seen on the north bank of the main Indian Creek. The steep walls that rise from the granite bench are formed of Silurian quartzites and limestone, with intercalated masses of hornblende trachyte. On the south side of Indian Creek, at the eastern end of the northern spur of Mount Holmes, the granitic rocks rise to the height of some 600 feet above the creek, and seem to have a rather uneven upper surface. They have some indications of bedding, with a sharp dip to the north. The granite is not so massive and compact as that shown at the south base of Mount Holmes, and has in places the appearance of a flinty quartzite in which are imbedded occasional large crystals of light-colored feldspar. At a short distance these rocks look like a metamorphosed conglomerate. Resting upon the rather uneven surface of the granitic rocks are very bulky sheets of hornblendic trachyte, which is a beautiful rock of a light-gray color (No. 18, Captain Dutton's catalogue). It is exceedingly compact, and the fallen masses break into large angular fragments with smoothly fractured faces. From the outer edge of this spur we have a fine view of the magnificent wall that rises on the north side of Indian Creek, the section exposed being one of unusual interest. We have a special section of a "laccolite," the structure of which is apparently identical with that of the laccolites of Colorado and Utah, which have been so well described in Mr. Gilbert's report on the Henry Mountains. There will be no better way of presenting this than by the accompanying sketch (Plate XIII). This sketch was made

a a Laccolite (sandstone) Trias? Mts
b b Sandstone (Jurassic)
d d Carboniferous limestone
c c Carboniferous limestone (Red Beds) Trias?
e Sepulchre Mt
f Emigrant Peak
g Valley of Gardiners River

PART OF INDIAN CREEK LACCOLITE,

LOOKING NORTH ACROSS THE VALLEY OF INDIAN CREEK

from the eastern end of the spur just mentioned, looking to the north across the deep valley of Indian Creek. The position of the laccolite wall will be understood by reference to the general view of the range as shown in Plate IX. To the right we have the valley of Gardiner's River, with Sepulchre Mountain and Emigrant Peak beyond. The length of the wall shown in the drawing is about 3 miles, and the height about 3,000 feet. The laccolite mass is well defined on the right, but on the left is much obscured by accumulation of *débris* Indeed, the valley of Indian Creek does not probably extend far enough to the left to reach the western limit of the mass, if the arch should even be symmetrical. Along the lower part of the wall and about 800 feet above the creek is a remarkably persistent wall of rock, that has a marked vertical jointage, which I afterwards determined to be composed of Silurian limestones. These limestones have a slight dip to the north, which is not visible from my point of observation. Resting upon the apparently horizontal limestone floor as a base, is the laccolite, which has, as can be clearly seen, separated the strata, and, by enormous accumulations of the molten material, arched the superposed strata over its domed summit. The strata which overlie the trachyte are probably mostly Carboniferous, as Carboniferous fossils occur at the right, but little above the eastern edge of the laccolite. The width of the laccolite from east to west is not less than 3 miles, and its thickness in the middle portion will not fall far short of 1,000 feet. There are a number of lines running across the steep face of the laccolite that are apparently included fragments of the sedimentary rocks, and probably mark the junction of separate intrusions.

In the bed of Indian Creek, beneath the base of the eastern edge of the laccolite, the granites appear. A low, wooded hill on the north side, at the exit of the creek from the mountain, is underlaid by these rocks. Between the hill and the laccolite wall is a depression through which an Indian trail passes. It appears to have been the trail used by the band of Bannocks who made a raid through the Park in August. It follows up Indian Creek and crosses the mountains to the head of the Gallatin River.

In ascending the cliffs to the base of the laccolite, I found first at the base a covered space of some 300 feet, with outcrops toward the top, and just beneath the great limestone wall of greenish-gray micaceous shales. These are probably the lowest Silurian rocks of this region and lie directly upon the granite. I found the great wall to consist of upwards of 300 feet of dark-gray limestones, which, although apparently at one time rather finely bedded, are now exceedingly compact. The vertical lines of weathering which have such a remarkable appearance at a distance prove to be owing to a rudely columnar structure, superinduced either by metamorphism or by some conditions of the weathering. I found no fossils, although the planes of bedding show many markings that are probably due to the presence of animal life at the time of their formation.

The laccolite is composed of hornblendic trachyte, in every respect like that on the south side. It is 400 to 500 feet thick at the point visited, but at the highest part of the arch is not less than 1,000 feet. The arched strata that overlie the laccolite, are, so far as the fallen masses indicate, yellowish and grayish limestones and siliceous limestones, without fossils. They comprise a thickness of from 500 to 800 feet. (See general section, Plate XIV).

Passing around the east face of the laccolite spur, I found, just be-

yond the end of the laccolite and a little above, a series of yellowish limestones which belong to the series passing over the arch of the laccolite. From these beds I obtained the following fossils:

Spirifer Rocky Mountainensis.
Athyrus subtileta.
Hemipronites crinistreata.
Zaphrentis Stansburyii.
Productus. (?)
Terebratula. (?)

The occurrence of the Carboniferous rocks so low down surprises me somewhat, as there can hardly be more than 500 feet interval for the Silurian strata, between this and the granite. In Mount Holmes there was apparently a much greater thickness. The thickness cannot well be determined until some approximate idea of the thickness of the intrusive sheets is obtained.

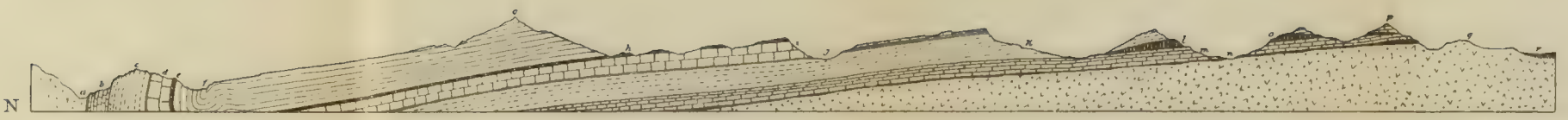
At camp, which I found on Panther Creek, far along the east base of the mountains, I observed that the drift contained fossil-bearing Carboniferous limestones, many of the species being the same as those enumerated above. Snow fell during the night to the depth of several inches, and the following day was spent in a successful elk hunt.

On the morning of the 12th we concluded to send the outfit to the Springs and close the season's work, as it was impossible to continue the topographical work, and geologic examination was by no means satisfactory. I spent the day, however, on the lower ends of the spurs that lie between Panther Creek and Electric Peak, and succeeded in completing, in a general way, the section of the sedimentary strata of this range, as given in Plate XIV.

From camp on Panther Creek, I passed to the north for about three miles, along the base of the range, and ascended the table-like spur at the first accessible point. The section exposed in the steep cliffs to the west of the place of ascent is as follows: At the base, less than 100 feet of hard rough-surfaced and brecciated limestone that probably overlies the fossiliferous limestones observed a mile or two farther south. Upon these rest the compact, massive, yellowish quartzites which form the main series of cliffs of this part of the range. There are upwards of 300 feet of these strata. Above these, and forming the upper part of the ledge, are 20 or 30 feet of laminated limestone and calcareous sandstones; these contain some indistinct impressions of fossils—probably a species of *lingula*—which would indicate the Jurassic age of the strata. Above the brink of the cliffs a steep slope reaches up to the top of the mountain.

The upper surface of this mountain is quite broad and has a slope conforming with the dip of the strata at an angle of 3° or 4° to the north. Far up the incline, toward the crest of the range, a few fragments of superior strata still remain upon the compact stratum that has so successfully arrested the progress of erosion. On the north there is an abrupt descent of about 500 feet to the valley of Fawn Creek. Here the compact quartzites are again exposed, but the limestones which occur at the base of the preceding section are beneath the creek bed and do not appear. North of the creek, I ascended a steep terraced slope, to the crest of the first great spur south of Electric Peak. At an elevation of 500 feet I reached an outcrop of coarse gray sandstone, some 30 feet of which were exposed. Near the summit of the ridge, at an elevation of 12,000 feet above the creek, some thin seams of limestone appear through the heavy alluvial deposits, in these are great numbers of a

Plate XIV.



a Yellowstone River
b Silurian (?) strata
c Cinnabar Mt Carb strata
d Jura-Trias
e Cretaceous-Dakota group
f Sharp fold in Cretaceous shales
g Electric Peak-Cretaceous
h Head waters of Gardiners River
i Jura Trias

LONGITUDINAL SECTION
THROUGH THE
EAST GALLATIN RANGE.
— 20 miles —

j Carboniferous beds
k Carboniferous beds
l Great Laccolite-Hornblendic trachyte
m Silurian Strata
n Indian Creek-Granite
o Laccolite-Hornblendic trachyte
p Mt Holmes-Silurian strata
q Granite
r Rhyolite of Madison Plateau

small spiral shell, that is thought by Dr. White to be Jurassic. Associated with the limestones is a seam of hornblendic trachyte having the same dip and strike as the sedimentary beds. Above this and forming the crest of the ridge is a heavy stratum of quartzite, beneath which, on the northern slope, I found the heavy conglomerate so characteristic of No. 1 Cretaceous. In this part of the range the strata rise at a slight angle toward the crest of the range, 3 to 4 miles to the west; in places—noticeably about the head of the main Gardiner, southwest of the base of Electric Peak—there are occasionally more abrupt dips, as much as 10° and 12° to the northeast. This spur is the first prominent one south of Electric Peak and descends in an irregular slope, composed of the Lower Cretaceous and possibly Jurassic rock, to the bed of the main branch of Gardiner River. North of this stream the Cretaceous strata appear in full force in the broad steep face of Electric Peak. At the base are a number of beds of sandstone probably belonging to the Dakota Group, upon which rest a thickness of 3,000 feet of dark slates and shales. It is worthy of notice that the dip and strike of these beds correspond pretty closely to the dip and strike of strata of corresponding age in Mount Evarts and the valley of the Gardiner about the Hot Springs.

Just what agencies conspired to break the continuity of the strata, I cannot determine. Much of the erosion has been accomplished by the present drainage, but the abrupt eastern wall of the Gallatin Range cannot have been produced in that way. The present valley of Cache Creek is probably due chiefly to erosion by its own waters, but the break in the strata, which at one time were continuous from the Gallatin Range to Mount Evarts, existed before the formation of the present valley, and even before the conglomerate deposits of Sepulchre Mountain existed. (See section, Plate X.)

Crossing the river at the point of its exit from the mountains, I ascended a low rounded ridge that reached far down into the broad valley of the Upper Gardiner. On the left there is a rather steep, wooded descent to the West Gardiner. Beyond this rise the smooth slopes of Sepulchre Mountain. On the right is the sage and grass-covered valley of the Main Gardiner. The exposures of strata are very limited, on account of the prevalence of drift materials. The summit of the ridge is composed of coarse basaltic conglomerate, which is like the conglomerates of Sepulchre Mountain.

UPPER GARDINER.

I have already pretty fully described the lower valley of Gardiner River. My acquaintance with the upper valleys, of which there are three, is almost entirely confined to the western, and but for the apparent simplicity of the geologic construction I would not attempt a description. Still, there are some very interesting points that may properly be mentioned here. Topographically, the chief features of the upper valley are the great plateau and the isolated mountain (Bunsen's Peak) that lies upon the plateau border, overlooking the Hot Springs, and which forms such a marked feature in the landscape of the neighborhood.

I have already described the manner in which the Cretaceous strata exposed in the lower valley pass beneath the sheet of rhyolite that crowns the opposing walls and circles the head of the valley, and mentioned the probability that this rhyolite sheet has at one time been continuous across the valley. It seems to me plain that at the time of the flow of these sheets of rhyolite the northern border of the great basin into

which the molten material was poured extended along what is now the southern base of Sepulchre Mountain, extending thence across the space occupied by Gardiner River to the highest point of Mount Evarts, and thence in an irregular line up the valley of the Yellowstone, but always to the south of the present bed of the river. At that period the valley of the Yellowstone did not exist, but in its place were the foot-hills of the Great Yellowstone Range, rising gradually from the brink of the lava lake, the borders of which I have partly defined. Why the valley of the Yellowstone happened to be formed where it now is, I shall not now attempt to say. I am convinced, however, that its formation was subsequent to the period of rhyolite flows, and that at the time it was laid out the waters of the Gardiner River Valley flowed out to the north on the upper surface of the lava floor until the Yellowstone was reached. The latter has since cut a bed 2,000 feet in depth along the northern border of the rhyolitic sheet, and the great valley of the Lower Gardiner is but a notch cut in the edge of the sheet. At three points, where the branches of the river descend, this cutting is still actively going on, but at a much retarded rate, as every foot of advancement to the south gives increased thickness to the lava cap and diminished thickness to the friable shales beneath. The three branches of the river are formed to the west, upon the upper surface of the floor of rhyolite, and before their union reach its edge and descend by splendid cascades the steep faces into the valley beneath. There has doubtless been a time when they formed a junction before descending from the plateau, and it is not improbable that one fork at least—the eastern —reached the Yellowstone without forming a junction with the other branches by passing down to the east of Mount Evarts. One cannot pass along the trail which leads through the low pass from the East Fork to the valley of Black-tail-deer Creek, without being convinced that at one time a stream occupied the depression. It is not impossible that the Yellowstone has occupied this part of the valley at one time, as the coarse river drift is everywhere found at and above this level from Mount Evarts to the Great Falls, but it is probable that the East Fork of Gardiner River occupied it much more recently. Such a change in the course of this stream could have been brought about by the deepening and expansion of the valley of the Middle Gardiner, which was first to penetrate the harder strata of the surface.

Now, there are a number of interesting facts that bear upon the erosion of these great valleys as to time. In the first place, the river drift, both of the Yellowstone and Gardiner Rivers, is found everywhere upon the upper surface of the rhyolite plateau, and that drift contains granitic materials which are not exposed on the south side of the river at as great a height as the summit of that plateau by fully 1,000 feet. It therefore had its origin either far up the river in the East Fork region or upon the northern side, lower down. In either case the river must have been at or above the level of the present plateau. It therefore seems plain that the present river valleys, 2,000 feet in depth, have been eroded since the period of rhyolite flows of the park district. Again, the very noticeable series of terraces that occur on the west side of Gardiner River, and on the northern side of the Yellowstone from Cinnabar Mountain to Bear Gulch and above, reach to the level of the rhyolite plateau, but apparently no higher.

Another interesting fact that should be noticed is this, that the great sheet of hot spring limestone capping the long ridge above Gardiner's Springs is on the upper surface of the rhyolite, and that its *débris* is mingled with the drift of the terraces. We have here, therefore, a very

a a a Valley of the Yellowstone
b Mouth of Gardiners River
c c East Fork of " "
d Falls of East Fork
e e Valley of Middle Fork
f Falls of " "
g g Valley of West Fork
h Falls of " "
i Upper valley of Gardiners River

LOOKING NORTH EAST ACROSS

THE UPPER AND LOWER VALLEYS OF GARDINERS RIVER.

FROM QUADRANT Mt – GALLATIN RANGE.

j Spur of Sepulchre Mt
k Mammoth Hot Springs
l Pass of Norris' Road
m Mt Evarts
r Long butte capped with old hot spr deposit
o Bunsen's Peak
p Spur of Washburn range
q Valley of Blacktail-deer Creek
r Volcanic ridge

interesting chapter in the history of these springs. They existed before the valleys of Gardiner River and the Yellowstone were laid out, and built their heavy sheets of deposit upon the level floor of the unbroken sheet of rhyolite that bridged the future valley. As erosion went on and the bed of the river sank, the springs sank and have followed step by step until now they issue from the hills, a thousand feet below their old level. The great series of terraces that grow less distinct as we ascend from the river attest the truthfulness of this conclusion. The geyser and hot spring action has been spoken of frequently as the last stage of the great volcanic activity of the later Tertiary age. Here we trace the hot-spring terraces far back as so many links that connect the far-distant past with the present without a break.

In Plate XV, I give an outline drawing representing the main features of the plateau border region as seen from the eastern flank of Quadrant Mountain, in the East Gallatin Range. In the middle part of the picture we have a glimpse of the lower valley of the Gardiner. In the foreground and on the right hand are the upper valleys of the Gardiner. To the right of the center is Bunsen Peak, a conical mountain (*a*) which ovrelooks the springs on the south. At the right, beyond, are the rounded forms of the northern part of the Washburn Range, and beyond this and extending across the picture to the left, the Yellowstone Valley, with the Yellowstone Range rising to its distant crest on the north. The dotted line marked *b* indicates the location of the mouth of Gardiner's River, which is at an elevation of 5,500 feet. The letters *d*, *f*, and *h* indicate the extreme head or heads of the lower valley. At *h* the West Fork descends in a cascade over the edge of the rhyolite highland. At *f* the middle or main Gardiner makes a corresponding descent, and at *d* we have the falls of the East Fork. The flat mass *m* with the steep wall fronting us is Mount Evarts, *m'* being the highest point, 2,200 feet above the river, and the northern termination of the sheet of rhyolite. Beneath, forming the cliff, are the Cretaceous shales. At the head of the valley, between the West and Middle Forks, is Bunsen Peak, the bulk of which is composed of a reddish or pinkish rhyolite. I was prevented from giving this mountain its proper amount of attention, and in consequence am quite unable to explain its occurrence at such a place. I am inclined to the opinion, however, that it can hardly be a relic of a former plateau of corresponding height, as there are no other remnants of equal height, and the amount of erosion required to reduce the whole of the plateau so many hundreds of feet is greater than the local drainings could have accomplished. It more probably marks the site of some center of eruption, where the accumulations of the rhyolite lavas were unusually great. The fact that the rhyolite appears so much deeper beneath the general surface here than at other points about the valley below, rather tends to confirm such a conclusion. According to the testimony of Dr. Hayden, who visited this mountain in 1871, the summit is capped with fragmentary basaltic material. Mr. Gannett brought away, at the time of his visit in 1878, a small fragment of hornblendic trachyte, which is identical with the fragmentary materials comprising the breccias of Sepulchre Mountain and Mount Washburne. To the left of this mountain and on this side of the deep valley of Gardiner River is the long ridge or narrow plateau *n* which has already been described as having a capping of hot-spring limestone with underlying rhyolites. To the left of this, and on the opposite side of Wagon-road Pass *l* is the rounded rhyolite hill *n'*, in the sides of which the Jurassic strata outcrop. To the left of this still we have the spurs of Sepulchre Mountain *j*, which have a capping

of rhyolite which corresponds to the capping of Mount Evarts at *m*, as also to the capping of the hill *n*, and the rhyolitic substratum of the plateau *n*. The basaltic and hornblendic trachyte conglomerates of Sepulchre Mountain extend down to the point *o*.

The West Fork of Gardiner River is a small creek that rises along the south base of Sepulchre Mountain, and runs down an open, grassy valley, upon a bed of drift. At *g* it turns abruptly to the northeast and descends through a rhyolite gorge to the lower valley. The main branch of the Middle Fork, which heads in the Gallatin Range south of Electric Peak, appears in the sketch at *i*, passing in a most sinuous course across the foreground to the right. After passing a considerable distance to the south it is joined by Indian Creek, and afterwards by Obsidian Creek. From the junction of the latter it turns to the north at a sharp angle, and descends into the lower valley at *f*. The low ridge (*t*), which may be seen extending down between the West and Middle Forks, is a much-prolonged spur of Electric Peak, that terminates near the mouth of Indian Creek. At the left it is capped with conglomerates and breccia, which are identical with the conglomerates and breccias of Sepulchre Mountain. Much of the ridge is covered by drift deposits, and the rounded, sparsely-tree-covered slopes abound in rich upland pastures. In the lower part of this ridge there are masses of basalt, the extent of which I am quite unable to define. It seems probably that they may underlie a large area of the drift-covered flats in the vicinity of the junctions of the main branches of the Upper Gardiner. The course of the main Upper Gardiner is much obstructed by beaver dams, as indicated by the sinuosity of its course. Before reaching the main descent into the lower valley at *e*, it passes through a shallow cañon, the walls of which are probably formed of the rhyolites. However, this particular region remains quite unexplored. Here, also, the pine forest prevails, and beyond this, extending to the valley of the East Fork *c*, there is but little open pasture land. Of this region I must plead total ignorance, excepting as to its general character, which is that of the other parts of the rhyolite plateau. The East Fork has its sources along the western base of the Washburne Range and passes through a number of small lakes. My only opportunity of observation in the western part of the Upper Gardiner Basin was enjoyed during a hurried trip from the Hot Springs to the Gibbon Geyser Basin, by way of Obsidian Creek.

Leaving the springs, we passed up through the pass *l*, and followed the Norris road down the valley of the West Gardiner, past the small lake *s*, and thence across the main Gardiner, and up Obsidian Creek. About the mouth of Indian Creek there are deposits of compact dark-gray basalt. Beyond this there are only the rhyolites and obsidians.

In ascending Obsidian Creek, by way of the wagon-road which connects Mammoth Hot Springs with the Geyser Basins, we pass first through broad meadows and parked forests. Farther on, the valley narrows up and the timber becomes extremely dense. At a point about 12 miles above the junction of the creek with the main stream, there is a narrow gateway, known as Obsidian Cañon, through which the road and creek pass. From the east side of the valley a low promontory extends forward to the creek and breaks off in an abrupt nearly vertical wall, in which the obsidian rocks are exposed. The road appoaches the cañon along the west side of the valley, and crosses to the east side at the lower end of the cañon; in order to avoid the swampy ground that borders the stream, it has been carried across the steep *débris* slopes of the obsidian cliffs. For a half mile it is paved with glassy

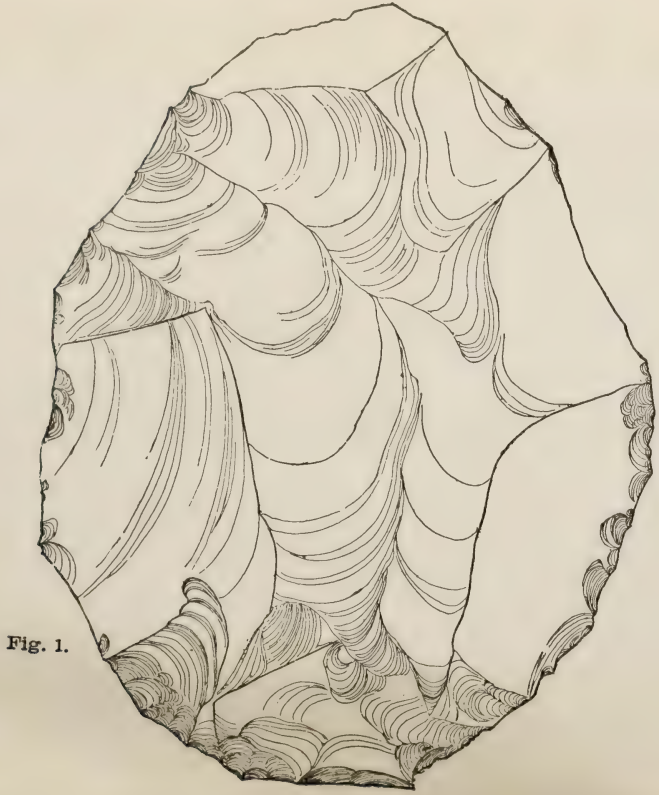


Fig. 1.

Fig. 2.

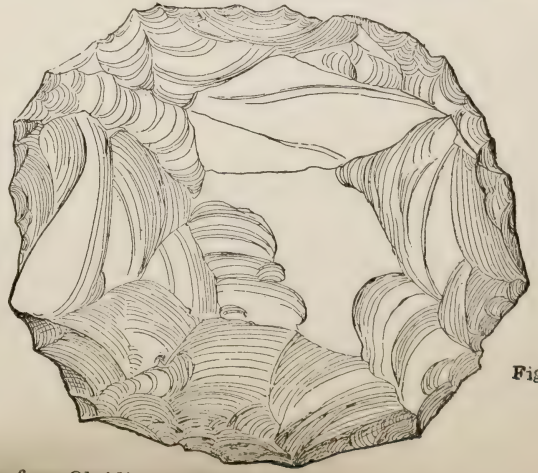


Fig. 3.

Plate XVI.—Implements of obsidian, from Obsidian Cañon.

fragments and lined by huge angular masses of black and banded obsidian rock. From the upper border of the *débris* slope the vertical cliffs rise to the height of nearly 200 feet. The lower half is composed of a heavy bed of black obsidian, which exhibits some very fine pentagonal columns, somewhat irregularly arranged and frequently distorted, but with perfectly cut faces that glisten in the sunlight. The upper portion of the wall is composed of a much more obscurely columnar mass of impure spherulitic obsidian, the rude faces of the columns being often as much as 10 or 12 feet across. To the right and left the columnar character becomes less marked, both in the upper and lower part of the cliff, and farther out seems to be entirely lost, the glassy rocks grading into the gray sanidin trachytes and obsidian porphyries of the surrounding hills.

Extending upward from the edge of the promontory in a moderately gentle slope are 400 or 500 feet of obsidian strata that exhibit some most interesting characters. There is no heavy mass of pure glassy rock, but a succession of irregular layers of a dozen or more varieties of spherulitic obsidian, obsidian porphyries, and breccias. The colors of these rocks are exceedingly varied, the prevailing blacks giving way to reds, browns, greens, and the richest possible marblings and mottlings.

One of the most striking characteristics of these rocks are the spherulitic concretions which occur to a greater or less extent in all the varieties. These bodies seem to prevail in the ashy-like bands or layers which, in the more compact mass toward the base, are frequently contorted, giving the rock the appearance of a banded and contorted gneiss. The ashy-appearing layers are probably composed of the same material as the concretions, since when we split the rock *with* the bands, the surfaces of the gray bands next the glassy layers are simply a connected or coalescent series of nodes or hemispheres, which have the usual appearance of the more isolated concretions. Where the concretions are scattered throughout the glassy mass, they are globular or composed of a cluster of globes. They have, in most cases, a distinctly radiated structure, with not infrequently concentric layers near the surface. The interior is gray or pinkish-gray, and the surfaces pinkish or flesh-colored.

In the coarsely columnar part of the wall the spherulites are often a foot or more in diameter, and appear much flattened and distorted. It is probable that these irregular forms are produced by the coalescence of a large number of smaller ones, as there are apparently many centers of radiation. Large beds of the rock seem to be made up almost wholly of the concretions, and, where decomposed, a mass of coarsely cellular or honey-combed obsidian remains. The brecciated beds consist of an ashy matrix, in which are imbedded angular fragments of every variety of the brilliantly-colored spherulitic and ordinary obsidians.

The collection of hand specimens made at this place is very complete, numbering upwards of three hundred. Their examination by specialists in petrography will doubtless develop many new and interesting features, as no equally rich deposit of similar rocks has heretofore been brought to their notice in this country.

Indian implements.—It occurred to me, while making examinations at this point, that the various Indian tribes of the neighboring valleys had probably visited this locality for the purpose of procuring material for arrow-points and other implements. A finer mine could hardly be imagined; for inexhaustible supplies of the choicest obsidian, in flakes

and fragments of most convenient shapes, cover the surface of the country for miles around.

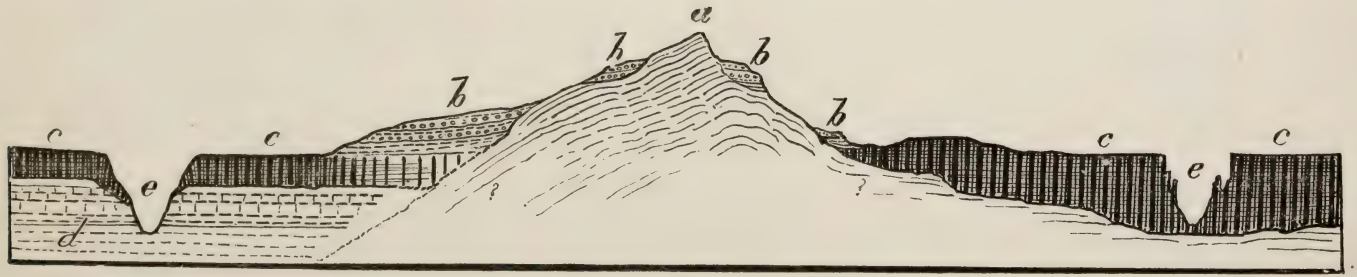
Having climbed the promontory, I observed that an old but quite distinct trail passed along the brink of the ledge and descended the broken cliffs to the valley above and below. In the vicinity of the trail the glistening flakes proved to be more plentiful than elsewhere, and were also apparently gathered into heaps. After a short search a leaf-shaped implement of very fine workmanship was found; it is made of the black opaque obsidian, and is 4 inches in length, 3 inches in width and one-half inch in thickness; an outline of this implement is given in Fig. 1, Plate XVI. Having continued the search as long as the time at my command would permit, I was amply rewarded in the possession of ten more or less perfect implements. Three are leaf-shaped and nearly the same in size as the first specimen found, but imperfect from having been broken. One is somewhat pyramidal in shape, as shown in Fig. 2; the bottom is flat, the flaked surfaces extending from the base to the apex; it is $2\frac{1}{2}$ inches in width and $1\frac{3}{4}$ in height, and is the only specimen in the collection that appears to have been in the least used; the sharp edge at the base is considerably worn; Fig. 3 is a top view of the same. Another specimen is triangular in shape, with sides about 3 inches long; another is rectangular and about 3 inches wide by 4 in length, and still another is a rude oval; nearly al of these implements are imperfect, as if broken or unfinished. If we are to suppose that the great quantities of minute flakes are the fragments left from the manufacture of implements, we must conclude that extensive supplies have been obtained here, but by what tribes or at what period it will be quite impossible to determine.

My observations in this region were too limited to enable me to determine the true relations of the obsidian rocks to the ordinary rhyolites that surround them. Their horizontal extent is a matter of conjecture. The western side of the valley rises in a steep, tree-covered slope to an elevation of about 600 feet, the rocks exposed along the base being gray rhyolites. Above Obsidian Cañon the valley expands somewhat, and is occupied by a shallow lake, about one mile in length by half a mile in width at the widest part. It is intersected by a complicated system of beaver dams. The water is strongly impregnated with alum and other impurities and is quite unfit for use. About a mile above the lake we cross the divide and enter the valley of Gibbon's Fork of the Madison. The general character of the formations remains everywhere the same.

In returning from the Gibbon Geyser Basin we turned up Indian Creek on our way to the Gallatin Mountains. There are but few outcrops of rock of any kind, and it is difficult to say just where the borders of the rhyolites are. In preparing the geologic map I have colored a broad belt along the west side of the Gardiner Valley as drift.

WASHBURN RANGE.

Of all the prominent mountain groups of the Park no one is so little known as the Washburn Range. Situated as it is in the midst of the Park and between two of the great basins of the wonderland, it has all along been simply an obstacle in the way of travel. It presents no feature of general interest, save the noble outlook obtainable from the chief summits. Travel has always been by the one pass which leads across the range near the west base of this peak. The several geologists who have visited the Park confined their observations to the vicinity of the



a Mount Washburn. *b* Breccias and conglomerates. *c* Rhyolite. *d* Tertiary strata. *e* Yellowstone Cañon north and south of Mount Washburn.

Plate XVII.—Probable relation of Mount Washburn to the rhyolite plateau.

pass and the main peak, and nothing like an analysis of the geologic structure has been attempted. The writer also unfortunately made but little advance over the information previously gained, not, however, for want of effort.

Our first passage of the range was made on the 6th of September, while *en route* to the supply camp at the Springs. The storms had effectually prevented a satisfactory study of the region about the falls and the upper part of the cañon, and I was glad to get a partially clear day to make a panoramic view from Mount Washburn. I was even prevented from completing my sketches by the storms of wind and snow, and close geologic study was out of the question. Our second visit to this region was rendered totally fruitless by the heavy snow-storms which finally drove us from the Park.

Topographically this range is very simple. A narrow range of rounded crests extends from Mount Washburn to the west for a distance of ten miles; thence an equal distance to the northward; and thence to the east about eight miles, thus forming three sides of a hollow square. Tower Creek drains the inclosed area, passing out to the northeast into the Yellowstone. The drainage on the north is into the Yellowstone by Black-tail-deer, Elk, and Geode Creeks; of the west and southwest, into the East Fork of Gardiner River, and on the south into Cascade Creek and the Grand Cañon. The range rests upon the floor of the great rhyolite plateau as a base, and has a general elevation of about 9,000 feet above the sea and 1,000 above the plateau.

With the geologic structure of this range I had considerable difficulty. A little additional study at a few points would clear up the obscurity that yet envelops the relations of the various groups of the volcanic Tertiary formations.

I shall first give briefly the details of my visits. On the 5th day of September I followed the Grand Cañon from the falls to the mouth of Sulphur Creek, and thence passed to the west across a broken table-land to the head of the Cascade Creek meadows. The rocks of the cañon are mostly compact rhyolites. On the higher parts of the plateau, between the cañon and Cascade Creek, there are heavy deposits of Obsidian strata. At the point where the trail reaches the base of the mountain there are considerable deposits of drift, composed of the disintegrated rocks of the range. A belt of this drift extends all along the base of the range, and at every point visited obscures the junction of the plateau formations with the formations of the mountains. The larger masses of the drift are compact hornblendic trachyte and andesite, such as occur on all parts of the range. The lower slopes are smooth and partially tree-covered. Higher up, dark, gnarled, massive rocks project from the slopes. The first outcrops observed along the trail are within perhaps a mile of the summit of the pass. They seem to consist of stratified eruptive rocks that dip at various angles and have a generally north-and-south strike. Beds of compact hornblendic trachyte alternate with basalts, compact conglomerates, and other rocks of poorly-defined species. None of these rocks, however, resemble in the least the horizontally bedded sheets that form the plateau. To the right and left of the pass we have the same formations, with probably some coarse conglomerates and breccias overlying them. In descending the northern slope, in the valley of Tower Creek, the upper 900 feet consist, so far as can be seen, of the same rocks. In the bed of a small branch of Tower Creek, which descends from the northern face of Mount Washburn, we came suddenly upon the horizontal rhyolites, at a level which corresponds very closely with the disappearance of the same

formations on the other side. There are no outcrops of the rocks of the summit sufficiently near to establish their superposition.

In ascending the northern face of Washburn I passed up a gulch that heads against the summit. At an elevation of 9,000 feet I encountered the trail that crosses the range by way of the first saddle north of the peak. A short distance above this trail the steep cliffs of the mountain begin. At the base of these, in the deeper gulches, there are outcrops of a series of bedded basalts and hornblendic trachytes that resemble those observed on the south side of the pass. The basalt is mostly reddish and brownish, as if considerably decomposed. It is full of cells which contain greenish grains, and often small concretions of chalcedony. Resting upon the upturned edges of these rocks are massive layers of horizontal breccias and conglomerates, composed greatly of dark, compact fragments of varied sizes, that appear to be basalts. There is also a large amount of finer ejectamenta. These rocks form steep, crumbling, and almost inaccessible cliffs. They do not seem to constitute the main body of the mountain, as the upturned hornblendic rocks project through them in places, but are filled into the irregularities of the pre-existing slopes and have had unknown horizontal extent. About the summit of the mountain we have a series of hornblendic trachyte, conglomerates, mixed conglomerates, and compact hornblendic rocks, that have great diversity of dip and strike. They appear to be the stratified ejectementa formed about the cones of ancient volcanoes. There are occasionally beds of basalt interbedded with the hornblendic rocks, but in no case are the rhyolites observed. The eastern spur of the range, which extends down to and overlooks the cañon of the Yellowstone, is also composed of the same series of rocks that constitute the peak, while the flanks and lower slopes show great deposits of the coarse conglomerates and breccias.

I was very desirous of getting a complete panoramic view from the summit of Mount Washburn, and spent all the time at my disposal in sketching, so that the geology was neglected. All visitors to this region agree in pronouncing the view from this point unequaled, and I may, with the knowledge of experience, add that it is one which is unusually difficult to place upon paper. The broad expanses of the great plateau, with its lakes, cañons, and poorly defined forest-hidden drainage, is an almost unintelligible maze which has no strong lines to tempt the pencil. The distant ranges of the south and west, and the very complicated tangle of mountains to the north, consume hours in their analysis, and days ought to be allowed for their proper delineation. This is the point from which the great problems of the Park should be studied. No other point gives such a comprehensive view of the extraordinary formations of the volcanic Tertiary period.

There are still a number of points that must be examined before all the difficulties can be overcome. The most important are the upper part of the valley of Tower Creek and the cañon of the Yellowstone beneath the east base of Mount Washburn. The latter point I was especially desirous of visiting, as the section is cut to such a depth below the plateau level that the relation of the plateau rhyolites to the rocks which constitute the core of the mountain will in all probability be shown. While in the region, however, I did not realize fully that this relation would be so hard to establish, or an extra day might have been spent in investigation.

The triangular spur that extends down between Tower Creek and the cañon is formed in the lower flattish part of the rhyolitic rocks. Extending down upon the flat portion from the summit of Mount Wash-

a Mt Washburn

b Yellowstone River, looking down - north

CAÑON OF THE YELLOWSTONE.

NEAR THE FOOT OF Mt WASHBURN

c.c Cañon walls rhyolites

d Probably beds of Conglomerate

e Amethyst Mt

burn are a number of spurs, formed of coarse basaltic breccias and conglomerates. The bedding is very irregular and there is a general inclination from the mountains of from 3° to 10°. The spur down which the trail passes is underlaid by the strata which constitute the interior parts of the mountain, as attested by a number of outcropping, upturned edges. In the loose material covering the slopes there are many fragments of sandstone and quartzite that are doubtless due to the breaking up of Tertiary strata. The valley of Tower Creek, as before remarked, is surrounded on three sides by the low ridge of the Washburn Range. The erosion over the greater part of the valley has been carried down to a general level corresponding to that of the rhyolite plateau, so that the observer gets the impression that the range is a connected series of cones built up subsequently to the formation of the plateau, by an accumulation of volcanic ejecta.

I am inclined to the opinion, however, that the range existed prior to the flow of the plateau rocks, as we have in no case found fragments of the plateau rocks included in the steeply inclined strata of the mountains, which is also true of the conglomerates. This could hardly be the case if the volcanic channels had penetrated the deposits of the plateau. On the other hand, if this range had existed prior to the rhyolite outflows, the molten materials must have been remarkably plastic to have filled in all the indentations on all sides so uniformly and completely. The chief difficulty, however, in determining the question lies in the fact that the breccias, which are surely subsequent to both the rhyolites and the hornblendic rocks of the mountains, lie upon the flanks of the mountains and obscure the junctions. The main channels of the stream have cut down into the plateau formations and flow at the bottoms of pretty deep cañons. The surface upon which the conglomerates and breccias were deposited seems to have been pretty uniform, with a slight inclination toward the north, and down toward the river, in the vicinity of Baronett's Bridge—has been pretty deeply eroded.

On the northern slope of the northern wing of the mountains, between Black-tail-deer and Elk Creeks, the conglomerates and breccias extend far down toward the third cañon of the Yellowstone. These formations are chiefly basaltic and seem to be associated with the numerous basaltic flows that occur in the same district. It is probable that the basalts and basaltic breccias were contemporaneous in their origin, and that their formation has continued down to a comparatively recent date. The location of the vents from which the lava issued cannot be made out, and as to the origin of the fragmental deposits, I do not wish to advance any theories. The bulk of those about Washburn have been formed of material derived from the mountain itself, and have more the appearance of sub-ærial deposits than any other in this part of the Park. In Plate XVII, I present a section which shows the relations of the various formations of the region to each other.

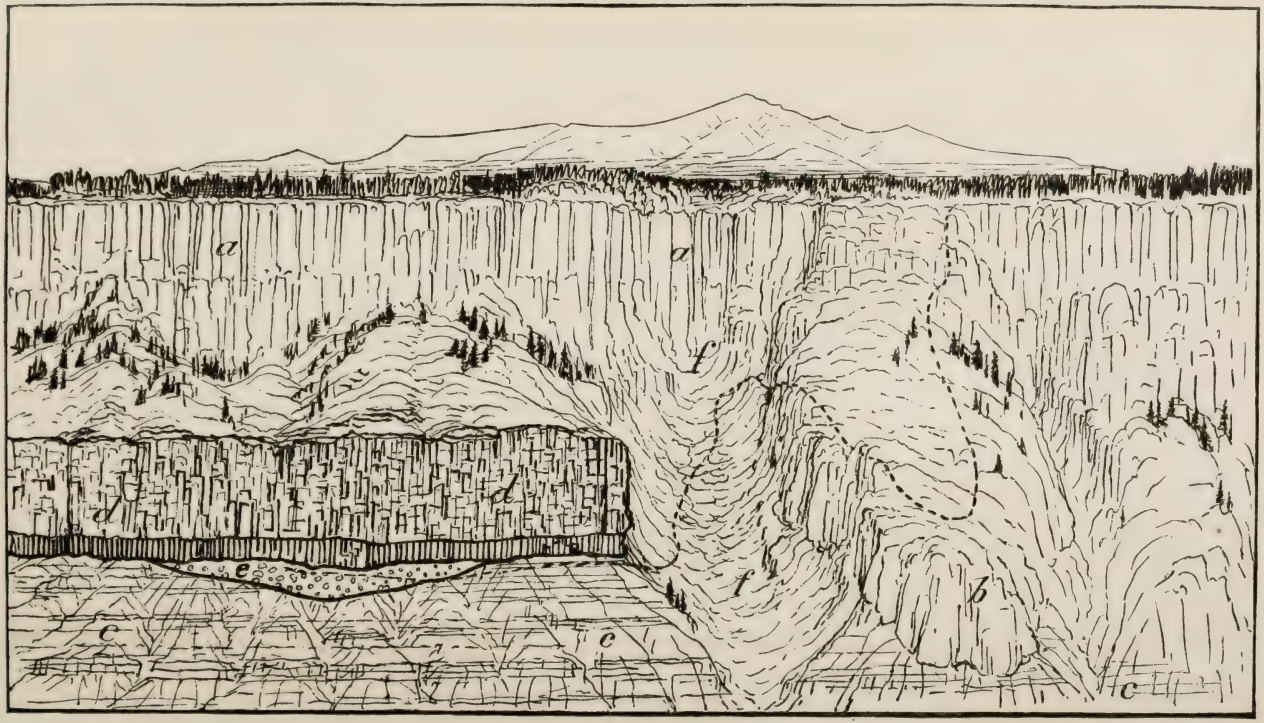
GRAND CAÑON.

From the summit of Mount Washburn we have the only comprehensive view of the Grand Cañon that can be obtained. The apparently bottomless gorge may be traced from its head at the Great Falls to Junction Valley, a distance of nearly 20 miles. From the falls to the base of Washburn Range it has a pretty direct northeast course. Below the Washburn Gap it curves slightly to the northwest and afterwards turns to the north. From the mouth of Agate Creek to Tower Creek the course is nearly northwest. I speak of the passage of the Washburn

Range as a gap for the reason that on the east side of the cañon there is a low, rounded ridge that seems to be a geological continuation of the Washburn Range. The cañon is everywhere quite abrupt, the walls descending from the general level of the plateau to the bed of the river without the interruption of shelves or terraces, yet the slopes are not so steep as to prevent the growth of dense forests over a larger part of their surface.

The exposed rocks are generally yellowish or brownish in color, and present very regular and continuous walls, indented by numbers of notches, very few of which cut back far into the plateau. All the tributary streams excepting Jasper and Broad Creeks run upon the upper surface of the plateau, or have but shallow valleys. All of the walls that can be seen from Washburn seem to be formed of rhyolite. In the cliffs about the mouth of the cañon of Broad Creek there are immense walls of yellowish-gray rhyolite which exhibit a marked columnar structure. The neighboring plateau up to the very brink of the cañon is densely timbered with the usual pine forest. The northern slopes of Washburn and the southern slopes of Amethyst Mountain beyond Agate Creek present a delightful contrast, however, to the somber forest, and abound in rich, grassy parks. The upper surface of the plateau at the falls has an elevation of 8,000 feet; at the base of Washburn also 8,000 feet, and between this and a point opposite the mouth of Tower Creek 7,200 feet. The depth of the cañon at the base of the Great Falls is 800 feet at the base of Mount Washburn 1,200 feet, and at Tower Creek 900 feet. The depth of the cañon may be therefore pretty fairly stated as 1,000 feet. The width is almost as uniform as the depth, varying from less than one-half mile to one mile. This cañon is without a doubt entirely one of erosion, and has been cut by the waters of the Yellowstone since the flow of the rhyolites and probably very greatly since the conglomerate-forming era.

On the 3d and 4th days of September we were in camp on Cascade Creek, near the Upper Falls of the Yellowstone. Heavy rains descended continuously and but little could be done. Early on the morning of the 4th a small party, consisting of Mr. James Eccles, an English geologist, Mr. Gannett, Mr. West, and myself forded the river at the head of the rapids and proceeded to the brink of the cañon, below the Great Falls. About two hours were spent in an attempt to measure the height of the falls. We descended a narrow, crevice-like gulch, and after considerable difficulty in the descent and a very dangerous passage along the face of the slimy walls that hug the torrent, found ourselves at the base of the falls, but such was the force of the whirling spray that we completed our work and retreated in the greatest haste, completely drenched. I should not advise any visitor to attempt the passage to this point without the use of ropes, as there is almost no hold for the hands and feet and a single slip on the damp, smooth rocks would precipitate him, without hope of rescue, into one of the wildest torrents that the world can show. The falls from below are inimitable, and, taken together with the cañon, form a picture without a rival. The lithologic characters of the cañon walls are very interesting and extraordinary. The formations consist almost exclusively of igneous rocks, which include a very great variety of rhyolites and pitchstones. Captain Dutton describes two specimens in his catalogue, Nos. 10 and 11. A feature of the walls below the falls is the occurrence of fragments of horizontal strata which have been built into irregular recesses and are thus shielded from erosion. They are generally coarse-grained sandstones or conglomerates and have very much the appearance of the lake beds which occur on the upper surface of the



a Rhyolite 300 feet thick. *b* Tongue of rhyolite extending down the slope. *c* Tertiary strata. *d* Bed of basalt 200 feet thick, columnar at base. *e* Bed of an ancient river. *f* Location of old vent.

Plate XIX.—A portion of the cañon wall opposite the mouth of Jasper Creek.

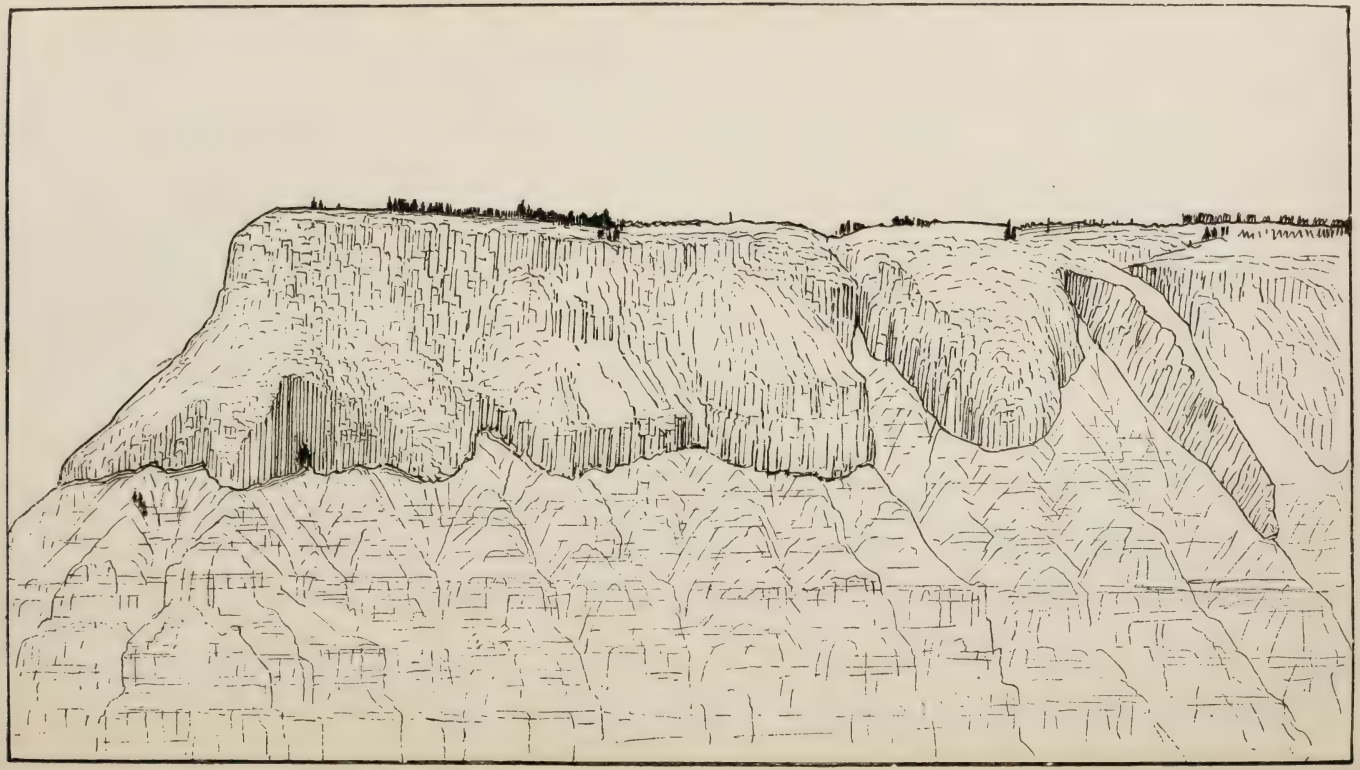


Plate XX.—A portion of the cañon wall.

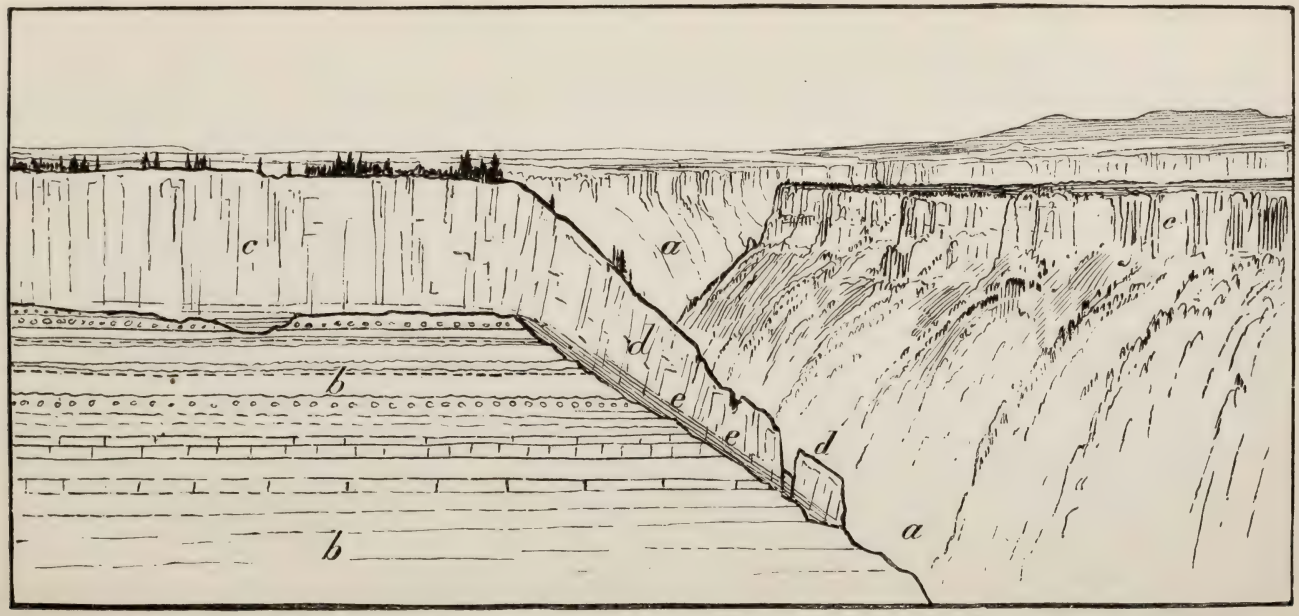
The sheet of rhyolite rests upon the Tertiary strata and extends in tongue-like masses down the slope.

plateau. If it could be ascertained that they really are lake beds they would take a very important place in our discussions of the erosion of this cañon and the drainage of the old lake, but it seems to me that they may be simply beds of alluvial material formed by the river before the falls had receded to their present position. At the falls, however, we are really within the borders of the ancient Yellowstone Lake, and the lake beds play an important part in the geology of the locality. The wall of the cañon between the Upper and Lower Falls, on the east side, is capped with about 20 feet of horizontally-bedded sandstones, under which are 30 feet of sandy clays. These are at a height of about 100 feet above the top of the Upper Falls. In the banks of the river, near the head of the rapids, similar strata outcrop at a height of from 100 to 150 feet above the river. The low, grassy hills that lie along the east side of the river, and the sage-covered terraces bordering the broad valley of Sour Creek, are probably composed chiefly of the lake beds. They occur also on the west side of the river both above and below the falls, and have their greatest development in Hayden's Valley, about 10 miles above. They rest upon the uneven surface of the pitchstones, rhyolites, and mixed, igneous rocks that constitute the body of the great plateau. In Plate XXXI, I give an approximate outline of the ancient lake in which these formations were deposited.

On the morning of the 5th I left the falls with the intention of passing down the western side of the cañon and between the cañon and Mount Washburn. At the request of Mr. Gannett I undertook to make a meander of the river course. The work proved to be very tedious, as it was quite impossible to know the approaches to the salient angles of the cañon wall on account of the dense timber, and much time was required to follow the sinuosities of the brink. Looking down from the cliff west of the falls, the view is cut off by a great white promontory, the steep, outer point of which projects forward and overhangs the river. This promontory is probably nearly a mile below the falls. The walls of the cañon, from the falls to this point and a short distance beyond, are extraordinary in form and color. They have already been described by many visitors. The rocks are all rhyolites (No. 9, of Captain Dutton's catalogue), mostly of whitish and grayish colors, which have been stained by the oxidization of minerals. As a rule the walls do not present broad, vertical faces, the peculiar jointage of the rocks having a tendency to produce steep buttressed slopes. Below the white promontory the character of the walls is greatly changed. The rocks are brownish and grayish rhyolites, which weather very dark, and are so amorphous and compact as to form walls remarkably steep and persistent. On the eastern side, beginning opposite promontory point and extending down nearly two miles, we have the finest wall exhibited anywhere in the cañon. The cañon is here about 1,000 feet deep, the upper half of the wall being a sheer precipice. The dark-brownish face is scarred and seamed in a most remarkable manner. There is apparently a tendency to the columnar structure. The joints have the greatest diversity of directions, extending in great sweeping curves across the wall, reaching from base to summit in almost straight lines or arranged in groups set at all angles with each other. Down the middle portion of this scarred wall a cascade falls. In the upper 500 feet the thread of water slides down the almost vertical groove which it has cut for itself. Below it strikes the *débris* talus and sinks from sight. The *débris* slope is for the most part covered with trees. An attempt to sketch this fine wall was defeated by a rain-storm, which, unfortunately, continued most of the day. At the lower end of the wall, and nearly three miles below the

falls, the river makes a bend, first to the east and then a little farther on, to the north, and soon afterwards into its course to the northeast. From the promontory, which overlooks the bend, we have a very good view down the cañon. (See Plate XVIII). The walls on both sides are broken down a good deal, and are partially covered with forest. There is much brilliant color in this part of the cañon, owing to the presence of hot springs, which seem to occur in considerable numbers on the slopes, more especially near the bottom on the west side. To the left, beyond, we have the profile of the eastern end of the Washburn Range, with Mount Washburn at the left. About two miles below the point of observation, and near the base of the Washburn Ridge, there is an escarpment of stratified rocks, which is apparently formed of volcanic conglomerates. Whether these beds are underlaid by the rhyolite rocks of the plateau, or by the fragmental materials that constitute the core of Mount Washburn, I am quite unable to say. It was quite useless for me to go farther in the heavy storms, as nothing could be seen with clearness beyond a very short distance, so I turned back and crossed to Cascade Creek, passing around the base of the foothills of Mount Washburn. The formations, wherever exposed, are of the rhyolites and obsidian porphyries of the plateau. Late in the evening I found camp at the summit of Washburn Pass.

On the 29th of September I made another attempt to follow the brink of the cañon from the falls to Tower Creek, but failed, the continuous snow-storms making such a feat impracticable. We broke camp at the mud geysers early in the morning. I had an opportunity of making some examinations at Crater Hill and at the falls, and had reached Sulphur Creek at the point of its descent into the cañon, when it became evident that the storm would continue throughout the day and night, and I sought camp at the head of the Cascade Creek meadows. The snow in places was already a foot deep. On the following day we crossed the range, and were delighted to find that the valley of the Yellowstone was almost clear of snow. On reaching the crest of the spur, which extends from Washburn down towards Tower Falls, I turned to the right across the base of the conglomerate spurs that lie between the branches of Antelope Creek, and reached the brink of the cañon at a point nearly opposite Jasper Creek. The cañon is here quite narrow and the walls steep, although not so precipitous as to prevent the growth of pine forest. The cañon of Jasper Creek is also very narrow, and the geologic formations are finely exposed in its steep walls. All that can be seen of the creek is a white, thread-like cascade leaping over the rocks into the river. To the left of Jasper Creek, and about half a mile below, is the mouth of the cañon of Agate Creek; and just beyond that is the naked wall which I examined while engaged in the study of Amethyst Mountain. I had some difficulty in finding a place to descend the cañon wall, but finally struck a broken spur (*g*, Plate XIX) that seemed to extend down to the river without vertical cliffs. In the spurs to my right and left were fine exposures of the geologic formations. Four hundred feet of the upper part consists of the ordinary gray and mottled rhyolite. Toward the top it is somewhat decomposed, and weathers down in heavy, rounded masses. Below come about 40 feet of yellowish, coarse-grained rhyolite with a rude columnar structure. The surfaces of the columns are rounded off by decomposition, and the tops are weathered into rudely conical points. Below this are about 100 feet of yellowish columnar trachyte, forming a fine vertical cliff. Toward the top the columns, which are generally pentagonal, are from 2 to 6 feet in diameter, but towards the base there is con-



a Yellowstone Cañon. *b* Tertiary conglomerates. *c* Capping of rhyolite. *d* Tongue of rhyolite extending down the slope. *e* Stratified tuffs.

Plate XXI.—Section in cañon wall, near Agate Creek.

siderable irregularity, the columns being smaller and much warped and indented. To the right of the spur which I descended there was a deep, narrow recess or gulch (*f*, Plate XVII), and beyond that an irregular spur, in the face of which I could see a mass of dark rock (*d*, Plate XIX) projecting from beneath the ledge of rhyolite that appeared to be conglomerate. Determining to examine it more closely, I descended into the deep gorge which intervened, and was not a little surprised to find myself in an old volcanic pipe or crater, three sides of which were still preserved, the other having broken down. Portions of the loose materials that had once filled the space are still clinging to the compact walls. They are scoriaceous materials and brecciated masses that seem to grade imperceptibly into the surrounding rhyolites. Judging by the remnants, the contents of the pipe have been of a most heterogeneous character. The light, often beautifully-colored scoriaceous breccias, are filled with pockets, which contain the greatest variety of rhyolitic fragments, pitchstones, sphærulitic obsidians, and volcanic bombs. Some of the latter are over a foot in diameter. At the back part of the pipe, and rising 200 feet above the slide of *débris* which partially fills it, is the wall of trachyte that forms the brink of the cañon. Crossing to the spur beyond, I found that the dark mass of rock which I had taken for a conglomerate was a heavy bed of black, finely-jointed rock that has the appearance of a basalt, although a specimen from the middle of the mass is pronounced an augite andesite by Captain Dutton (No. 27, catalogue). This bed of rock, which I shall continue to call basalt on account of its perfect resemblance to other unidentified rocks that I have found it convenient to class as basalts, is nearly 200 feet thick, and forms a steep ledge, which extends for a considerable distance along the middle part of the cañon wall. At the base there is a columnar band some twelve feet thick, which rests upon a great series of Tertiary strata, sandstones, and conglomerates. These strata are horizontal, and where in conjunction with the basalt are much metamorphosed. They extend down to the river bed, some 400 feet below. In following along the base of the sheet of basalt I came upon the section of an old river bed (*e*, Plate XIX) which had been filled up by the basalt. The stream had flowed in a shallow bed eroded from the Tertiary conglomerates. The well-rounded pebbles, extend over a width of 150 feet, and are of a great variety of rocks, the granitic, however, prevailing. That part of the basalt which lies in the old river channel has, on the under surface, a layer of pumice about a foot in thickness.

Something of the past history of this valley can be learned from the facts here observed. A stream—whether the Yellowstone or not, no one can say with certainty—had cut down through the Tertiary strata to a depth of 600 feet below the top of the present valley, and about 400 above the bed of the present river. The lava has flowed into it, filling the valley to the depth of 200 feet or more. Whether this occurred before or after the flow of the rhyolite I am unable to say from any facts observed, although on general principles we would probably be safe in concluding that it is more recent. The *débris* at the ends and on the top of the mass of basalt make it difficult to say whether it passes beneath the rhyolite of the main wall of the cañon or is simply set against it. The fact that it does not continue across the crater to the right, as seen in the drawing, proves nothing, as the rhyolite, which extends down the opposite spur to a point considerably below the base of the basalt, may have been deposited either before or after it. I had not time to go on with this interesting investigation or I should, without a doubt, have been able to solve the whole problem of the relative

ages of all of the cañon rocks. During the short interval between storms I had a good opportunity of studying the interesting features of the opposite side of the cañon. The relations of the rhyolite sheets to the Tertiary conglomerates and sandstones are evident at a glance. In the north wall of Jasper Creek and in the promontory that overlooks the Yellowstone between Jasper and Agate Creeks there are some interesting phenomena (Plate XX). The great sheet of rhyolite is from 300 to 400 feet thick and forms the escarpments of the walls on the north side of Jasper Creek. At the top, for a thickness of about 100 feet, the ledge is broken and partly tree-covered. Beneath this follows a magnificent wall, some 300 feet in height, in which we have a series of the most perfect columns, straight, regular, and generally vertical. In one place the columns are exposed to the full height of the wall. At the base of the steeper part of the wall is a dark recess that is probably a cave, the result of the crumbling away of the soft deposits at the base, which here seems to consist of a dark band of porous pitchstone underlaid by white, bedded tuffs similar to those of Mount Evarts. The rhyolites are yellowish and reddish-gray in color. These igneous rocks rest upon the rather uneven surface of the Tertiary strata. The latter formation extends down to the river in dark, deeply lined and buttressed slopes.

Back in the cañon of Jasper Creek, a fourth of a mile or more, there occurs a most interesting feature which, more than anything else I have seen, throws light upon the topographical character of the surface upon which the rhyolites were flowed. It is clear at a glance that at that period a cañon existed where Jasper Creek now runs. The rhyolite flows have, on reaching the brink of the old cañon, poured down its sides and filled in the valley, the line of contact being now plainly exposed, sloping at an angle of nearly forty-five degrees. The drawing (Plate XX) will make my meaning clear. As would be expected, there is a tendency on the part of the columns, which are characteristic of this rhyolite, to form at right angles to the plane of the base of the sheet. Whether or not this flow entirely filled the old cañon it is difficult to say, but the fact that the upper surface of the rhyolite sheets has such a uniform general level, tends to show that all irregularities of the old surface were totally obliterated, and that the subsequent drainage has probably been formed without regard to the preceding, and that the occurrence of a modern river on the site of an ancient channel is merely an accident. Following the face of the sheet of rhyolite from Jasper Creek around to the end of the promontory overlooking the Yellowstone, we can see the same tendency to curve down the slopes of the cañon, although the erosion has been carried back so far as to obliterate the inclined part of the sheet. On another occasion, while making examinations on the Amethyst Mountain side of the cañon, I examined closely a similar case of inclined flow, which I will describe further on. The walls of the cañon on the east side, above the mouth of Jasper Creek, are so broken as to allow of the growth of considerable forest. There are numerous outcrops of rocks, however, and along the middle of the slope there is a ledge that has the appearance of basalt. It is possible that it is a fragment of the same flow that I had just examined on the west side, but may be interbedded with the rhyolites as others appear to be farther down.

When I had emerged from the cañon it was already late, and I had to make all haste to reach camp on Elk Creek. Following the brink of the cañon I encountered two troublesome gulches or side cañons before reaching Tower Creek. One of these was Antelope Creek, which I crossed pretty high up so as to avoid the cañoned part. The rocks, so far as they

are exposed, appear to be rhyolites. On the opposite side of the cañon the capping of rhyolite could be traced with ease. At Agate Creek it is from 300 to 400 feet thick. The upper surface is quite flat, and, extending back to the slopes of Amethyst Mountain, there are broad meadows. The rhyolite sheet seems to thin out toward the northwest. The Tertiary formations, which form the greater part of the cañon wall, rise higher and higher until, at the point of the promontory, opposite the mouth of Tower Creek, they reach the top of the wall and the sheet of rhyolite feathers out and falls back from the cañon brink. It is exposed, however, on the north side, facing East Fork. At one place a mile or more above the mouth of Tower Creek, there is a break in the sheet or sheets of rhyolite. A later sheet seems to have flowed over the eroded edges of a former one so as to give the appearance of a non-conformity. The rhyolites extend down to the mouth of Tower Creek. They may be seen both above and below the falls. They appear in the bed of the creek near its mouth, and in the highest point of the short ridge that overlooks the falls on the east. Strangely enough the rhyolites do not reach across the creek, the western bank being formed of basalts and Tertiary strata, mostly conglomerates. At the falls these rocks occur on both sides and form most of the high towers for which the locality is noted. These rocks also extend down to the bed of the stream below the falls. The strange relation of the rhyolites and conglomerates I was not able to make out for want of time. From what I could see, the creek must flow along the line of an old Tertiary cliff against which the rhyolites flowed, otherwise we have here a point of outflow, and the rhyolites that occur in the creek bed low down occupy the old rents. The presence of rhyolitic breccias and tuffs at the Devil's Hoof confirm this. This locality has often been described, and I have but little to offer that is new. The character of the conglomerates and their relations to the volcanic rocks can be studied here to great advantage.

On a previous day, while engaged in the study of Amethyst Mountain, I descended to the brink of the cañon on the north side near the mouth Agate Creek. In descending from the ridge that extends to the westward from the main summit of Amethyst Mountain, I found that the conglomerates reached to the base of the steep slopes, and that the table-land which extends from the cañon to the base of the mountain is composed entirely of the rhyolites. To all appearances these rocks pass beneath the conglomerates of the mountain. In descending the cañon wall I passed down over about 200 feet of light, yellowish rhyolite, and found below the well-known Tertiary conglomerates; these extend down to the river in a rather gentle slope, which is broken midway by a partially wooded terrace. At my left, and inclining with the slope at an angle of 50°, I found a tongue of rhyolite (*d*, Plate XXI) extending down over the conglomerates, precisely as I saw them on Jasper Creek. The base part of the mass was dark, resembling a pitchstone, and identical with the lower part of the great sheet which caps Mount Evarts. Beneath this, and separating it from the conglomerates, is a bed of finely-grained white and gray tufaceous sandstone (*e*, Plate XXI), which also is precisely like the similar formation in Mount Evarts. This locality is, perhaps, two miles below that previously described opposite the mouth of Jasper Creek. The mist which prevailed at the time prevented me from making satisfactory observations of the opposite walls of the cañon. The upper third evidently consists of the coarsely columnar rhyolite. Beneath this, appearing through the pretty dense covering of trees, were two ledges of dark, very perfectly columnar rock that may be basalts. The geologist who attempts to study the

cañon should follow the north side from the bridge to the mouth of Jasper Creek, descending at three or four points to the base of the rhyolite capping; once at Jasper Creek, near the cave shown in Plate XX, again midway between that point and the falls where there is some irregularity in the flows, and finally at the mouth of Tower Creek. On the south side there are several points within the same distance, but the key to the whole situation will probably be found at the last base of Mount Washburn.

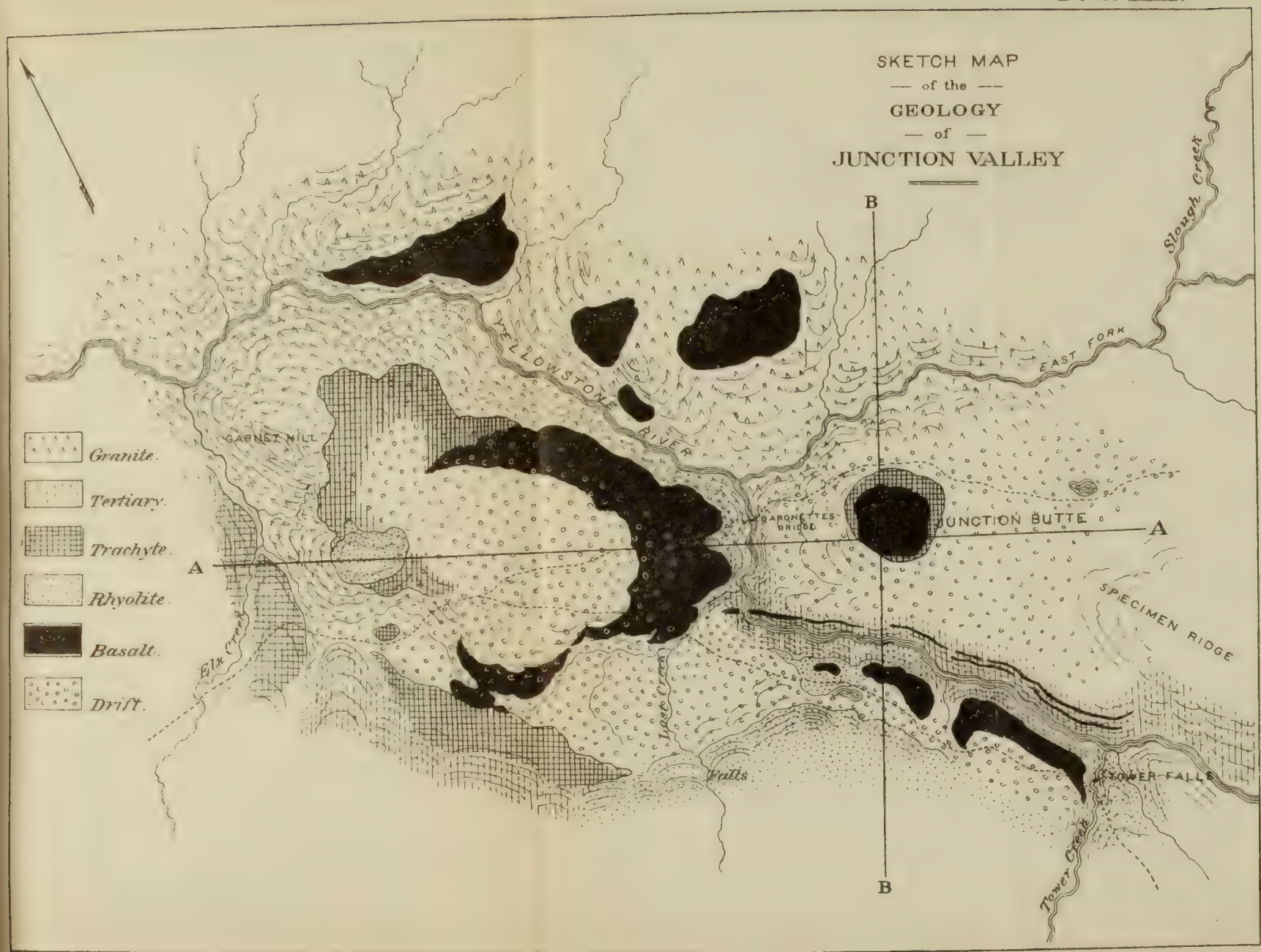
JUNCTION VALLEY.

This valley is situated in one of the most interesting as well as one of the most beautiful regions in the Park. The geologist might find a year's profitable work within a radius of 10 miles about Baronett's Bridge, and the tourist could find almost unlimited sources of pleasure. Geologically there are illustrations of many of the most interesting problems of geological history, and the very perplexing events of the "Volcanic Tertiary" period may be studied to the best advantage.

North of the valley rises the great range of Granitic Mountains that must have looked down in succession upon the Eocene, Miocene, and Pliocene lakes, and witnessed the extraordinary events of the volcanic period. Here, during the latter part of the volcanic epoch, while the subaerial deposits were in process of formation, the erosion seems to have been more than usually deep. The trachytes and rhyolites were poured out into valleys cut in the Tertiary and Paleozoic rocks. Subsequent flows filled in the valleys eroded from the first flows, and so on through the basaltic and conglomerate producing period, on account, however, of the occurrence of so many products together their relations are hard to make out. This may be remarked of the Tertiary strata especially, the several groups of which cannot easily be distinguished from the conglomerates formed in more recent times through alluvial and volcanic agencies, and positive identifications are very nearly impossible. Of course prolonged study may make everything clear.

Dr. Hayden has already given a very good general account of this locality in his annual report for 1872, and others have given it casual attention. I shall give as much additional detail as seems to me desirable. The map (Plate XXII) will give a pretty correct idea of the surface relations of the various formations.

In following the general course of the Yellowstone Valley from below, it will be seen that the East Fork is its direct continuation, occupying a line along the base of the granitic range, while the main river crosses the volcanic plateau from the southeast, reaching the granite in Junction Valley. The channel of the East Fork is in the granites in the lower 10 miles of its course. The main river runs from the bridge to the western base of Garnet Hill over a granite bed. Below this for a short distance it has not yet penetrated the full thickness of the Tertiary strata. Garnet Hill is the largest body of granite occurring anywhere on the south side of the river. The granitic rocks are generally distinctly stratified, and have a northwest and southeast strike, with a steep dip to the northeast. The more compact layers, which consist of feldspathic granite and mica schists, form pretty marked ridges that run at right angles to the course of the river, and may be traced far up the uneven slopes of the Yellowstone Mountains. On the south there is an irregular and much broken ascent from the channel of the river to the general level of the rhyolite plateau, an ascent of approximately 1,000 feet. Aside from the main Yellowstone, however, there is no important stream draining into Junction Valley from the south. Among


SKETCH MAP
— of the —
GEOLOGY
— of —
JUNCTION VALLEY
Granite.
Tertiary.
Trachyte.
Rhyolite.
Basalt.
Drift.
GARNET HILL
YELLOWSTONE RIVER
EAST FORK
Slough Creek
BARONETTES BRIDGE
JUNCTION BUTTE
SPECIMEN RIDGE
Elk Creek
Lost Creek
Falls
TOWER FALLS
Tower Creek
A
A
B
B

the most striking topographical features of the valley and vicinity are the broad, drift-covered meadows, lying between Elk Creek and the base of Specimen Ridge, Junction Butte, the well-known landmark of the valley, and Garnet Hill, which lies at the lower end of the valley.

Garnet Hill consists of a heavy angular mass of dark schistose rocks that have their direct continuation in corresponding strata north of the river. From all surrounding points and from many points on the trail its steep rugged walls catch the eye. The summit is covered with stunted pines. On the east the dip of the strata gives a rather gentle incline toward the meadows and river. Close under the southwest face is the little stream known as Elk Creek, and the Yellowstone rushes with great force through a ragged cañon at the north base. The rocks consist of alternating mica schists and coarse-grained granitic seams. The bedding is quite irregular and there is considerable contortion, as if the strata had undergone great pressure. Garnets occur in the greatest quantity and can be seen dotting the faces of the exposed rocks or may be picked up where they are weathered out and mixed with the soil. All are very much flawed and so filled with impurities that they can never have any particular value. Lying against the eastern and southern flanks of Garnet Hill are the outcropping edges of a sheet of peculiarly brecciated trachyte (Nos. 1, 2, and 3, of Captain Dutton's catalogue) which presents a variety of colors, running through all grades of red, purple, orange, and even green. It rests directly upon the schist and is apparently the oldest of the volcanic products of this district. At various points in the valley of Elk Creek there are outcrops of this rock. It is first encountered on the trail in approaching from the Mammoth Springs, shortly after descending the steep Tertiary wall that borders Elk Creek on the west. This is at an elevation of some 500 feet above the river and at least a mile from the point at which the trail enters the Elk Creek Meadows. It also occurs in the low cliffs which border the meadows. It may be seen in a curious triangular mound, from 1 to 3 feet in height, that lies in the midst of the smooth meadow. On our left, as we pass by the mound, is a low, flat-topped hill (from which the sketch given in Plate XXIII is taken). Along the base of this there is a dark ledge of the brecciated trachyte that at first sight would be taken for basalt. At the left base of this hill, facing Elk Creek, the garnetiferous schists outcrop. The hill is capped by a mass of grayish rhyolite (No. 4, Captain Dutton's catalogue) which is similar to the rhyolite of the plateau. Between this hill and the bridge, a distance of upwards of a mile, the surface is covered mostly with drift, such outcrops as occur being chiefly basalts. In passing over this drift-covered terrace to the north, keeping close to the base of Garnet Hill, we find the reddish brecciated trachyte outcropping in a ledge that overlooks the Yellowstone, where it turns to the north around Garnet Hill. As we pass to the right, up the river, however, the trachytes soon give way to basalts and the only rocks from this to the forks are of the latter kind.

Along the southern side of the valley, midway between the bridge and Elk Creek, and near the low pass in the meadows, where the Elk Creek drainage meets the Lost Creek drainage, there are low bluffs formed of the brecciated trachyte. Here it is chiefly greenish in color, but in other respects is identical with the trachytes elsewhere. There are also basalts in the vicinity, but in what relation to the trachyte I am unable to say. One small mass of this basalt (No. 29, Captain Dutton's catalogue) occurs in the lowest part of the low pass just mentioned.

The steep slopes that reach up to the plateau on the south side of the valley are composed of Tertiary conglomerates and rhyolites, the former prevailing towards Elk Creek and the latter towards Tower Creek. The trachytes are probably younger than the conglomerates, although in many places they seem to pass beneath the conglomerate walls. This appearance is doubtles the result of their having been filled into sharply-cut depressions in the Tertiary rocks.

The brecciated trachytes are found again in Junction Butte, where they may be seen on the north side, beneath the capping of black basalt. Here the color is reddish yellow. The weathered surfaces and *débris* slides are almost as dark as the basalt. There is not a large exposure, although it is probable that the layer forms the base of the butte and rests upon the granites. These trachytes are nowhere more than 200 feet in thickness and occur at an elevation above the river of from 100 to 600 feet. It is not improbable that they all belong to the same flow and that the old valley was filled up to a pretty general level by that flow. The sheets of trachyte had undergone a large amount of erosion prior to the flow of the basalts. The rhyolites, which belong chiefly to the plateau flows, descend to the valley in two or three places. As mentioned before, the low hill that lies between Garnet Hill and the Elk Creek Meadows is capped with a mass of light-gray rhyolite that closely resembles the plateau rhyolites. Beneath the rhyolite we have the brecciated trachyte. Between the bridge and Tower Creek the rhyolites outcrop along the brink of the shallow cañon, beneath sheets of basalt. At the bend of the river, near the mouth of Lost Creek, there is an outcrop of rock that resembles a rhyolite but which has the appearance also of a sandstone. It is probably disintegrated rhyolite recompacted. West of this, toward Elk Creek, the rhyolites occur in the plateau face and form the upper part of the cliffs. They extend back toward the south and pass beneath the conglomerates of the Washburn Mountains. The small stream which I have called Lost Creek, because it apparently sinks from sight in the lower part of its course, falls over a high wall of pinkish-gray rhyolite at the point of its entrance into the valley.

I have already described the manner in which the rhyolites occur at the mouth of Tower Creek.

The basalts of this valley form an important geologic feature. Dark masses of this rock may be seen on all sides. These are remnants of a few flows or sheets, however, as attested by the uniformity of levels. In age they are evidently the youngest of the volcanic products, and have been poured into the valley at so late a period that it had reached almost its present conformation.

The old river channel has been obliterated, and the irregularities in the granites, tertiary sedimentaries, trachytes, and rhyolites filled in. The highest occurrence of the basalts is about 600 feet above the river bed at the forks, and the lowest is within less than 100 feet above the river. Since the flow of the basalts, the river has therefore cut through the 500 feet of basalt, and nearly 100 feet into the underlying formations. How nearly the river runs in its old channel it is difficult to say. There seems to have been a tendency on the part of the river to shift toward the base of the granite range in this part of its course, if we are to judge by the distribution of the river drifts. The great body of the igneous flows are at present on the south side of the river. On the north side, below the junction, there are a few remnants representing at least two distinct flows, which are set into depressions or recesses in the granites. Fronting the river these remnants break down

b Mts. at East Fork and the south Yellowstone
c Canon of Barronelles bridge
e Valley of East Fork looking up
d Junction Butte
e Northwest View
f Head of River
g Cliffs with basaltic columns below Tower Creek
h Canon of Tower Falls
i Grand Canon
j Hayden plateau
k Mts. of the Absaroka
l Mts. of the Gallatin

JUNCTION VALLEY.

FROM THE SOUTH BASE OF GARNET HILL

[illegible] BOULDERS

a.a Yellowstone River.

b b. Fragments of basaltic sheets

BASALTIC REMNANTS.

NORTH OF THE RIVER

JUNCTION VALLEY.

c.c. Gneissic rocks.

in steep cliffs or bluffs, and dark slides of the finely-divided rock extend down the slopes. The drawing given in Plate XXIV will give a good idea of their appearance, and the accompanying map will show their location. Farther down, in the vicinity of the mouth of Hell Roaring Creek, there are other remnants, but evidently belonging to different flows.

A greater part of the drift-covered mesa that occupies the middle part of the valley between Elk Creek and the bridge is underlaid by sheets of basalt, and some idea of their extent and thickness may be obtained from the outcropping ledges near the bridge and below. Although the outlines are very indefinite, it is probable that the basalts of this valley do not altogether occupy as much as one square mile of surface. The thickness will probably reach 200 feet, but it may be that there are intercolated beds of sedimentary or alluvial deposits. There is no outcropping ledge more than 20 feet in thickness. On the side next the river, just below the forks, there are some pretty well developed columns.

In passing to the west from the bridge, we ascend the basaltic mass by way of a rounded depression or notch in the east face. When we reach the highest level we find that there is a general but gentle slope toward the west. The whole surface is drift-covered. We are here about 400 feet above the river. The capping of basalt on Junction Butte is some 200 feet higher, and unless the sheet flowed upon an incline, or has been subsequently tipped, must belong to a higher flow than any other of the remnants of the valley. It is less than 200 feet thick, and in color quite black. It breaks down in minute, irregular blocks.

I present in Plate XXIII a sketch of the valley, looking east from the low rhyolite hill near Elk Creek. In the foreground we overlook the rounded, drift-covered mesas of the middle portion of the valley. At the right we see a small portion of the drainage of Elk Creek, connecting through the low pass (*m*) with the Lost Creek Meadows. At the extreme right we have the border of the rhyolite plateau. Lost Creek descends from the plateau at *r*. The course of the river may be traced, coming from the right, crossing the middle of the picture, and coming out to the left. We look directly up the sinuous valley of East Fork (*c*), the junction being at *a*. The granites are exposed in the sharp bluffs on both sides. It will be seen that Junction Butte (*d*) rises from a drift-covered mesa which lies between the two rivers. Beyond the butte, a little to the right, is the point of Specimen Ridge (*p*), and beyond we can see the ridge which leads back to Amethyst Mountain (*e*). Between the higher part of the ridge and the cañon there is a plateau-like belt on which there remains a portion of the great sheet of rhyolite (*t*) that once extended across the space now occupied by the valley. The Amethyst Ridge formed the northern border of the basin in which the rhyolites were deposited. The main body of the ridge is composed of Tertiary strata and conglomerates. North of the East Fork we have rugged hills rising toward the mountains.

In the drawing I have indicated the trail, which divides in the middle of the drift-covered mesa, the left branch crossing to the bridge and the other turning to the right, crossing Lost Creek near the bend of the river and continuing up the west bank toward the mouth of Tower Creek at *h*. In the wall which extends from *b* to *g* we have some of the most puzzling phenomena of the region. The main formations of the wall are rudely but horizontally bedded conglomerates, which, unfortunately, I had no opportunity of examining closely. To all appearances

they belong to the same series of conglomerates that occur about Tower Falls, and form the walls of the cañon above Tower Creek. They are apparently continuous with the formations that constitute the bulk of Amethyst Mountain, and which by the evidence of their flora are Miocene or Pliocene. The interesting feature is this: that a number of beds or sheets of basalt are intercolated with the conglomerates in the wall of the cañon. This basalt is beautifully columnar, as every visitor to the region knows, and the outcropping edges of the sheets are very uniform in thickness and quite persistent horizontally. It is safe to say that they are not intrusions but contemporaneous flows, and therefore, since they are interbedded with the conglomerates, that they are older than the rhyolites of this region, as the latter uniformly overly the conglomerates.

On the opposite side of the cañon the butte *o* is capped with a mass of basalt underlaid by rhyolite, beneath which are the conglomerates. Table rock at Tower Falls is also formed of basalt. The bed to which it belongs is quite massive, but so far as I have seen not columnar. In the walls of Tower Creek, above the trail, this bed of basalt curves down and apparently extends beneath the bed of the creek. Under the basalt are greenish sandstones and conglomerates. That the strata upon which the basalts and rhyolites of the south side rest are Tertiary I have no doubt. The beds in which the columnar basalts of the opposite side lie are apparently the same, but may possibly be more recent. An examination of the conglomerates ought to determine this question, since, if they are younger than the other strata of the region and subsequent to the rhyolites and trachytes, they will contain fragments of the rhyolitic rocks which abound in the locality from which their materials must be derived. I am strongly of the opinion, however, that none of these rocks will be found in this formation, and hence expect that time will demonstrate that all these valley conglomerates are older at least than any of the rhyolites.

I present two sections, A and B, Plate XXVI, which will show the relations of the various formations of this part of the valley.

With the lower end of the valley I have only a limited acquaintance. West of Elk Creek a steep, irregular slope leads up to a high promontory—an outstanding spur of the Washburn Mountains—that overlooks the third cañon of the Yellowstone, opposite the mouth of Hell Roaring Creek. In ascending this eminence by way of the trail from Elk Creek we pass up very steep slopes to a gap or saddle just west of the highest point of the promontory, and find at the base some 500 feet of the brecciated trachytes. These rocks seem to outcrop all along the Elk Creek base of the promontory. They are identical with the brecciated trachytes of the valley. The main wall of the promontory is composed of Tertiary strata, sandstones, and conglomerates, with possibly some Post-Tertiary conglomerates above.

In 1872, Dr. A. C. Peale obtained a number of species of Tertiary leaves from the sandstones near the trail on the Elk Creek side of the promontory. Toward the base, on this side, the sandstones are fine-grained and grayish and greenish in color. They alternate with compact conglomerates, and are pretty evenly bedded. The materials which form the conglomerates are only moderately coarse, and are chiefly, if not altogether, composed of basaltic or andesitic materials. The mass is frequently so compacted that it breaks with an even fracture, the sections of the constituent fragment appearing on the surface. These fragments are never well rounded, yet do not seem to be sharply angular. Higher up and in the sides of the gorge, through which the trail passes

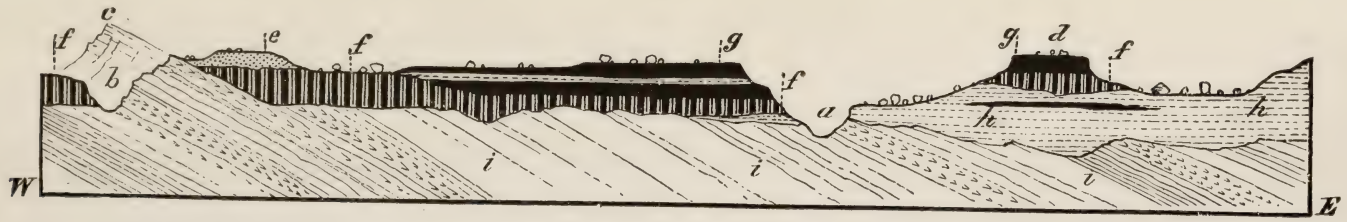


FIG. 1.—Section A, Junction Valley

a Yellowstone River. *b* Elk Creek. *c* Garnet Hill, garnetiferous schists. *d* Junction Butte, basalt cap. *e* Rhyolite. *f* Trachyte. *g* Basalt. *h* Tertiary strata. *i* Mica-schists, Granites, &c.

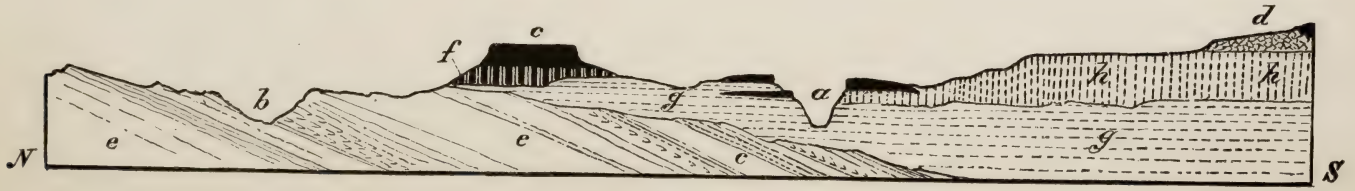


FIG. 2.—Section B, Junction Valley.

a Yellowstone River. *b* East Fork. *c* Junction Butte, basalt cap. *d* Spur of Mount Washburn, conglomerates. *e* Granites and schists. *f* Trachyte. *g* Tertiary strata. *h* Rhyolites.

Plate XXVI.—Geology of Junction Valley.

before reaching the open upland, the materials are much coarser, consisting frequently of great angular masses of basalt and probably also andesitic and sedimentary rocks. There are also considerable columns of dark and ferruginous basalt. Geodes of banded agate and chalcedony are very abundant. The basalts are very abundant on the rather gentle slopes that extend from the trail downward to the cañon. The Tertiary strata, however, appear frequently, and even extend down to the bed of the river in a few places. As mentioned before, the river is mostly in the granites, but near Hell Roaring Creek it is in the conglomerates. At one point they form a sort of gateway of picturesque cliffs. In a number of places the basalts reach down to the river, and in a few instances occur in small bodies on the north side.

I have not seen this region thoroughly enough to make a good map of it, as the conglomerates, basalts, trachytes, and schists occur without the least regularity. My study of this locality has unfortunately in every case been of the twenty-five-mile-a-day kind. My knowledge of the cañon between Garnet Hill and the mouth of the Black-tail-deer Creek is limited to the memories of a hurried trip in 1872, and such glimpses as were afforded by a visit to Garnet Hill in 1878.

One of the most noticeable features of this valley is the occurrence of drift deposits, and especially of huge masses of granite on the various benches about the forks from the river bed to the level of the great plateau 1,000 feet above. These granite masses have doubtless been brought down from the valley of the East Fork, as they correspond in lithologic characters to the massive granites that occur from 8 to 10 miles above the junction. Their transportation has begun with the beginning of the erosion of the valleys, and they have been deposited on the various flood-plains formed as the river descended through the rhyolitic plateau and its underlying formations.

EAST FORK AND AMETHYST MOUNTAIN.

The valley of the East Fork of the Yellowstone is one of the most enchanting in the Park. For nearly 20 miles above Junction Valley it is broad and smooth, abounding in meadows and terraced grass lands. On the north rises the massive range of the Yellowstone Mountains, and on the south the peculiarly interesting walls of Amethyst Mountain. Twenty miles above the bridge the valley narrows up and is pretty densely timbered, but the upland region about the headwaters abounds in delightful parks. The beds of the various tributary streams are generally in rather precipitous valleys from 500 to 1,000 feet in depth.

The two main tributaries from the north, Slough Creek and Soda Creek, emerge from deep-cañoned valleys, which they have cut in the massive volcanic formations of the Yellowstone Range. On the south side a dozen or more small streams of clear water descend from Amethyst Ridge.

In the lower part of its course the river is in the granites, which here, as at the forks and below, have a strong dip to the east. About 9 miles above the junction a massive stratum of reddish, feldspathic granite forms a low ridge across the valley, this seems to have offered very determined resistance to the progress of erosion. The valley is here more than a mile wide, and the river seems, in times past, to have oscillated from side to side, descending with great force over the granite ledge, detaching the great bowlders that now appear so plentifully in all the valleys below. At present the river has cut a deep and narrow passage through this belt of granite far over toward the north side of the valley. Above

this the valley is wide and smoothly terraced, the terraces for the most part being underlaid by thin sheets of basalt, which may be seen outcropping on both sides of the river.

The belt of very compact granite is evidently the most easterly exposure of these rocks in this valley, as they are overlaid by limestones which appear on the trail a short distance above the last exposure of granite. On the north side of the river the line of contact between the granite may be traced by a depression which follows the strike of the latter. Further back toward Slough Creek the limestones appear in force, and on the broad plateau to the northwest of Slough Creek seem to lie in massive strata nearly horizontally upon the granites. Limestones again appear near the trail on Amethyst Creek, and at the mouth of Soda Butte Creek we have 500 or 600 feet of limestones; from these I obtained Carboniferous fossils. These strata are everywhere apparently horizontal and rest unconformally upon the granites.

The paleozoic formations have very limited exposures in the deep valleys. They underlie the massive formations of the so-called volcanic Tertiary age, which in this region reach their maximum development. These strata rest upon the unevenly-eroded surfaces of the paleozoic and granite rocks, and form a great part of the mountain ranges that inclose the valley. They are horizontal, and apparently conformable thoughout the entire thickness of 5,000 feet. The greater part of this immense group of strata is filled with the silicified remains of ancient forests.

The section given in the accompanying plate occurs in the north face of Amethyst Mountain, opposite the valley of Soda Butte Creek, and includes upwards of 2,000 feet of strata. The bed of the river is at an elevation of 6,700 feet above the sea, and the summit of Amethyst Mountain 9,400. On the north side of the valley, near the mouth of Soda Butte Creek, there are between 300 and 400 feet of Carboniferous strata exposed along the base of the mountain slope. On the south side occasional ledges of limestone appear above the detrital deposits. The valley is here less than a mile in width, and is covered with thin sheets of basalt.

The north face of Amethyst Mountain does not present as abrupt a profile as that given in the section, the middle part only being so precipitous. At the base and top there are comparatively gentle slopes; nevertheless the actual stratigraphical conditions are truthfully represented.

As we ride up the trail that meanders the smooth river bottom, we have but to turn our attention to the cliffs on the right hand to discover a multitude of the bleached trunks of the ancient forests. In the steeper middle portion of the mountain face, rows of upright trunks stand out on the ledges like the columns of a ruined temple. On the more gentle slopes farther down, but where it is still too steep to support vegetation, save a few pines, the petrified trunks fairly cover the surface, and were at first supposed by us to be the shattered remains of a recent forest.

In ascending one of the steep spurs that project from the main wall, the strata were found to consist, toward the base, of shales and fine-grained sandstones. Higher up conglomerates occur, and still higher coarse conglomerates and breccias prevail. Interbedded with the massive, irregular beds of the latter rocks are always thin layers of sandstones and shales. The sandstones are fine-grained, thinly bedded, and contain more or less tufaceous material. Their prevailing color is greenish and greenish gray. They are apparently composed chiefly of material derived directly or indirectly from volcanic sources. In no case are

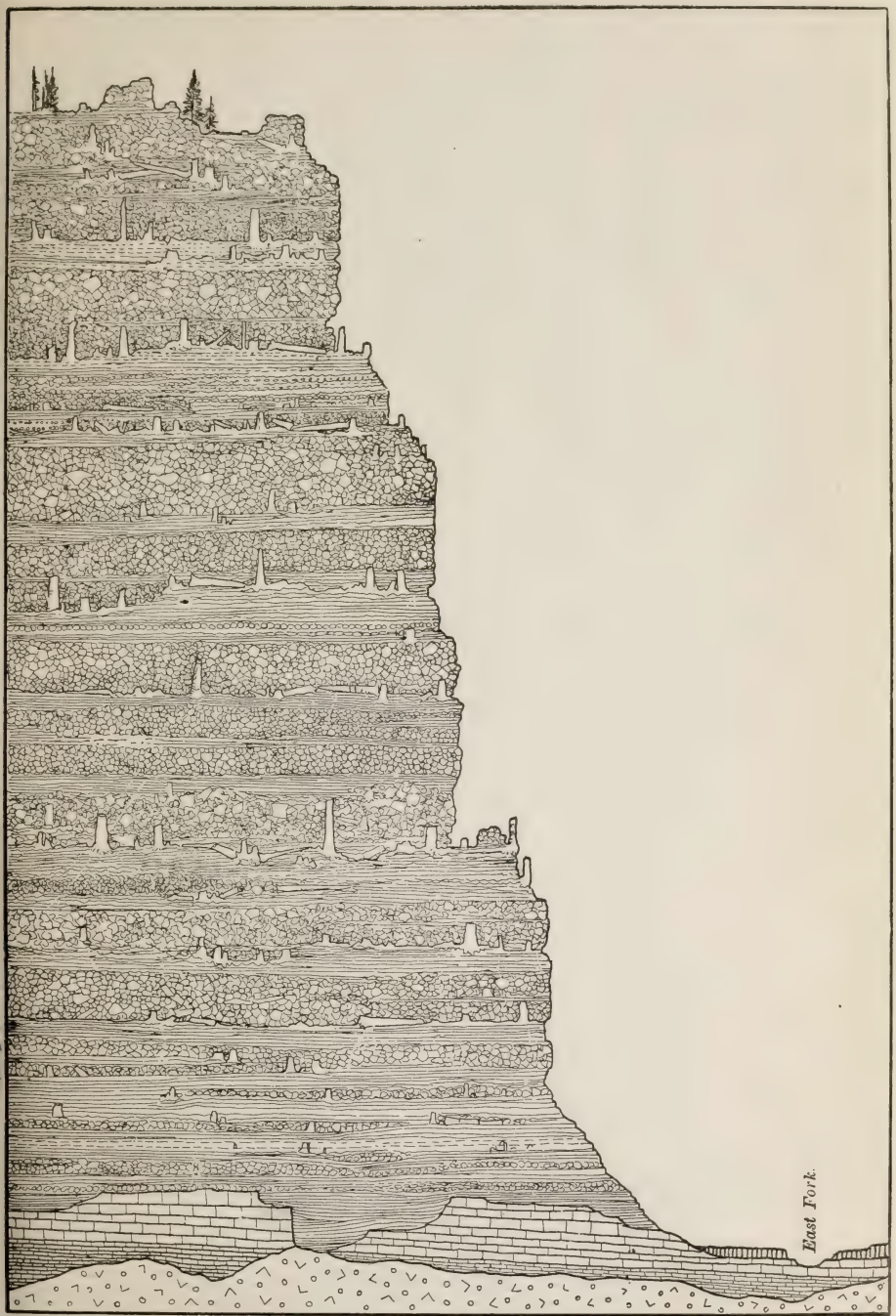


Plate XXVII.—Section of Amethyst Mountain, showing Fossil Forests.

pebbles of quartz or other granitic constituents found in either the sandstones or conglomerates.

The exposures of strata in the first three or four hundred feet at the base are not good, and but few of the silicified trunks appear above the covering of vegetation. At the height of 500 feet the occurrences become very numerous, and the great size and fine state of preservation of many of the trunks was a matter of much surprise. Prostrate trunks, 40 and 50 feet in length, are of frequent occurrence, and not a few of these are as much as 5 or 6 feet in diameter.

The standing trunks are generally rather short, the degradation of the compact inclosing strata being so slow that the brittle trunks break down almost as fast as they are exposed. In many cases the roots are exposed, and may be seen penetrating the now solid rock with all the original ramifications. One upright trunk, of gigantic proportions, rises from the inclosing strata to the height of 12 feet. By careful measurement it was found to be 10 feet in diameter, and as there is nothing to indicate to what part of the tree the exposed section belongs, the roots may be far below the surface, and we are free to imagine that there is buried here a worthy predecessor of the giant *Sequoias* of California. Although the trunk is hollow, and partly broken down on one side, the woody structure is perfectly preserved, the grain is straight, and the circles of growth distinctly marked. The bark, which still remains on the firmer parts, is 4 inches thick, and retains perfectly the original deeply-lined outer surface. Specimens of the wood and bark were collected, but no microscopic examinations have been made. It is clear, however, that the tree was not a conifer. The strata which inclose this trunk are chiefly fine-grained greenish sandstones, indurated clays, and moderately coarse conglomerates. As would naturally be expected, these strata contain many vegetable remains: branches, rootlets, fruits, and leaves are extensively inclosed. One stratum of sandstone that occupies a horizon nearly on a level with the present top of the giant tree contains a great variety of the most perfectly preserved leaves. Such specimens as we were able to bring away with us have been submitted to Prof. Leo Lesquereux for identification. They are found by him to belong to the Lower Pliocene or Upper Miocene, and correspond in a number of their species with the Chalk Bluffs specimens of Professor Whitney. They include—

Aralia Whitneyi,
Magnolia lanceolata,
Laurus canariensis,
Tilia (new sp.),
Fraxinus (new sp.),
Diospyros (new sp.),
Cornus (new sp.),
Pteris (new sp.),
Alnus (new sp.), and a
Fern (new sp.).

It will be observed that most of these species are new, which was also the case with the collection of Professor Whitney. It is also worthy of remark that none of the genera are identical with those of the Elk Creek locality previously mentioned. The stratigraphical relations of the two localities cannot easily be made out, as they are separated by 15 miles of broken country, in which the strata are obscured by igneous flows and Quaternary drift. The Elk Creek strata are lower by fully 1,000 feet.

As far above the leaf-bearing horizon as I was able to ascend, the silicified trunks were very numerous and well preserved, and, by the aid of a field-glass, others could be detected in all parts of the cliff to the highest stratum.

At another point, nearly a mile farther east, I climbed the rugged walls of the mountain for the purpose of examining a number of large trees visible from below. Trunks and fragments of trunks were found in great numbers and in all conceivable positions. In most cases the woody structure is well preserved; the trunks have a tendency to break in sections, and on the exposed ends the lines of growth, from center to circumference, can be counted with ease. In many cases the wood is quite completely opalized or agatized, and such cavities as existed in the decayed trunks are filled with beautiful crystals of quartz and calcite. Our party was so fortunate as to procure some very handsome specimens of amethyst and ferruginous quartz. It is a matter worthy of observation that nearly all of the beautiful crystals occurring so plentifully in this region have been formed in the hollows of silicified trees. The same fact has been noticed in regard to similar crystals in many parts of the West, and notably in the case of the smoky quartz of the Pike's Peak region in Colorado.

The silicifying agents have been so unusually active in these strata, that not only are all organic remains thoroughly silicified, but all cavities in the loosely bedded rocks and all fracture-lines in the strata are filled with chalcedony or other forms of quartz.

On reaching the heavily bedded conglomerates of the upper third of the cliff, I found the trees still more perfectly preserved. Many of the trunks are 20 and 30 feet in height. Their roots are in most cases imbedded in the layers of finer-grained materials in which they grew, while the battered and branchless trunks are encased in the coarse conglomerates and breccias. These latter rocks are composed chiefly of basaltic fragments, many of which are of great size; there is, however, always enough tufaceous and other fine-grained material to fill in the interstices and act as a cement. These beds are massive and irregular, and seem to have accumulated too fast to be thoroughly redistributed by the waters. In most cases where upright trunks penetrate the entire thickness of an inclosing bed, the tops may be seen to terminate with the upper surface of that bed, as if causes had acted at the beginning of the deposition of the succeeding stratum to plane down the irregularities of the old surface. In due course of time, this succeeding stratum produced its growth of forest which, in its turn, was buried by the rapidly accumulating conglomerates.

The very precipitous character of the cliffs prevented my reaching the upper part of the wall at this point, but I succeeded in making my way to the summit of the mountain at two other points, and found that everywhere the section was practically the same.

On the opposite side of the valley the same conditions were observed: the fossil trees occur at the highest point reached, 3,000 feet above the river. The ranges forming the rim of this valley on the north and east reach an elevation of 11,500 feet, and as the conglomerates may be seen reaching and forming the loftiest summits without perceptible break or change of character, it is probable that they will be found to inclose the remains of forests throughout.

I am totally at a loss to determine just where the truly subaqueous sedimentary rocks end and the subaerial begin, as there is no well-marked break.

There are probably three distinct groups of the Tertiary formations,

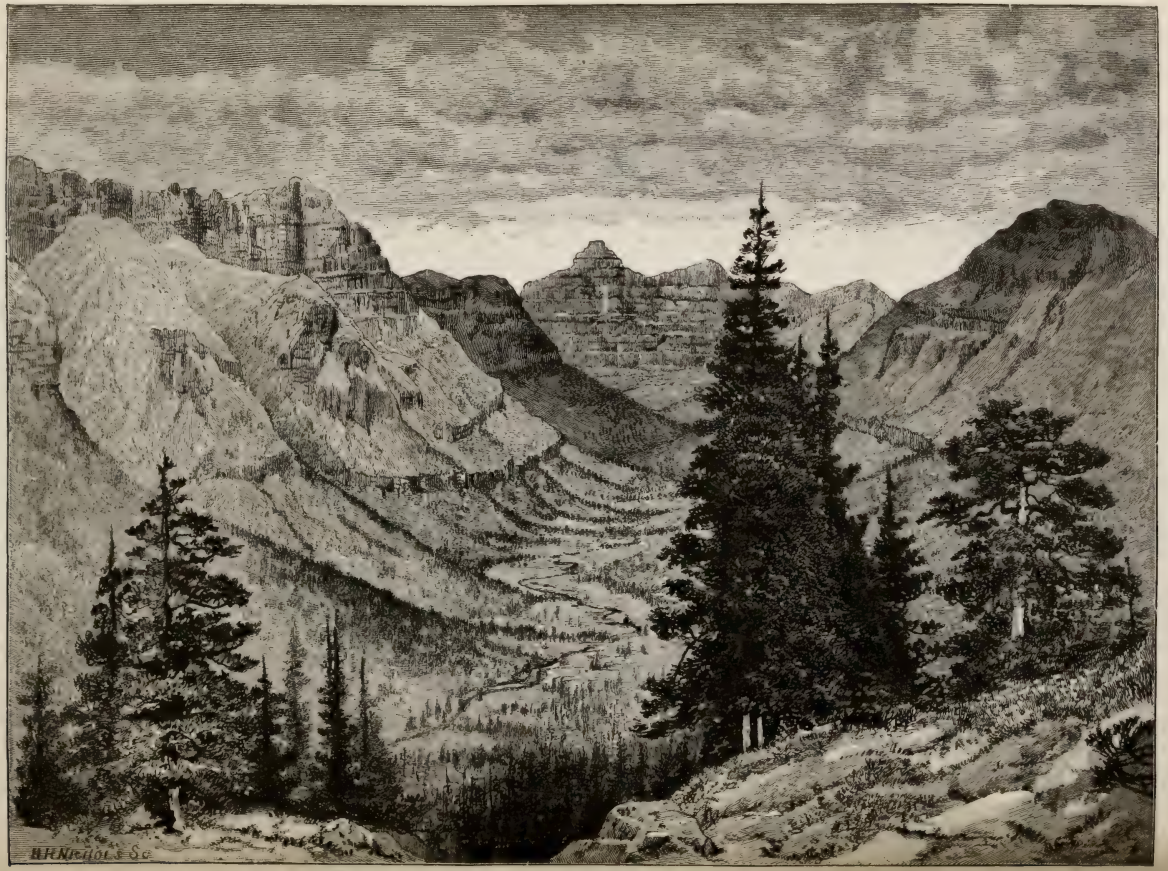


Plate XXVIII.—Valley of Soda Butte Creek, showing stratified conglomerates.

VOLCANIC BRECCIA SUMMIT OF TO-GWO-TEE PASS.
HEAD OF WIND RIVER.

although they are much alike in character and materials, being composed greatly of unworn fragments of eruptive rocks. There is, first, the group of strata occuring in the vicinity of Junction Valley, in the walls of the cañon beneath the great rhyolite flows, and which form the lower part of the strata of Amethyst Mountain. They are undoubtedly the oldest of the Tertiary rocks of this region. They are older than the flow of the rhyolites and basalts, and contain, according to Lesquereux, Eocene flora. To all appearances they are truly sedimentary in their character. They contain, so far as I know, but few fossil trees.

The second is a more widely distributed group that contains pretty well but irregularly stratified materials, most of which are coarse and irregular, and are chiefly andesitic, trachytic, and basaltic. In the East Fork district they reach a thickness of 3,000 or 4,000 feet, and cover large areas. They lie apparently conformably upon the earlier groups, and the precise horizon where the first ends and the second begins is not determined. In many cases they appear to rest upon the rhyolites of the plateau, and where found in contact with the old volcanic ranges abut horizontally against them. They contain great numbers of the remains of Miocene and Pliocene forests. In many places they have the appearance of ordinary sedimentary rocks, but more frequently present the appearance of alluvial drift or of direct subaerial deposits. The abundant occurrences of forest would find a more ready and consistent explanation if the latter idea were adopted. Captain Dutton has spent a number of seasons in the study of a great series of similar formations in the plateau regions of Utah, and has come to the conclusion that they are wholly of alluvial origin. He presents the matter in a clear and forcible light in his valuable report on the plateau region of Utah.

The third group forms the cores of the great volcanic ranges around which the horizontal beds are built, and from which much of their material was derived. I have observed rocks of this group both in the Washburn Mountains and in the great range east of the lake.

The two days to which our visit to the valley of the East Fork was limited, were spent mostly in the examination of Amethyst Mountain. On the third day I crossed to the valley of Soda Butte Creek, and thence up the river to the first large tributary that enters from the east. The valleys are terraced and drift-covered, and the slopes of the mountains are composed of the usual volcanic conglomerates.

Camp was made in a high valley near the head of the second stream east of Amethyst Mountain. The rocks are unusually coarse conglomerates. Some of the massive spurs overlooking the river on the south are capped with heavy sheets of basalt.

On the following day we crossed the divide of Amethyst ridge and found ourselves on the headwaters of what is probably Broad Creek. It is a remarkable fact that the crest of the ridge is composed of rhyolite, which seems to occur in layers with strong dips in divers directions. In following the divide to the east, I found that while the rhyolites form the crest and are the chief rocks of the broken plateau which extends southward toward the lake and cañon, the northern slopes of the ridge are composed of basalts and conglomerates. The elevation here is generally about 9,000 feet. There is considerable conglomerate *débris* scattered over the surface of the rhyolites of the plateau. In the region of the divide lakes, which were visited by the survey in 1871, the formations are all rhyolite. These are light in color, distinctly bedded, and have very numerous and large sanidins and quartzes.

The abrupt basaltic promontories bordering the deep valley of East Fork on the south afford a fine view of the country about the head-

waters of that river. The geologic formations are apparently entirely volcanic. The bold promontory from which I made my observations is formed of massive sheets of dark, coarsely crystalline basalt, that show in the vertical faces some pretty fine columns. These basalts are apparently associated with the conglomerates.

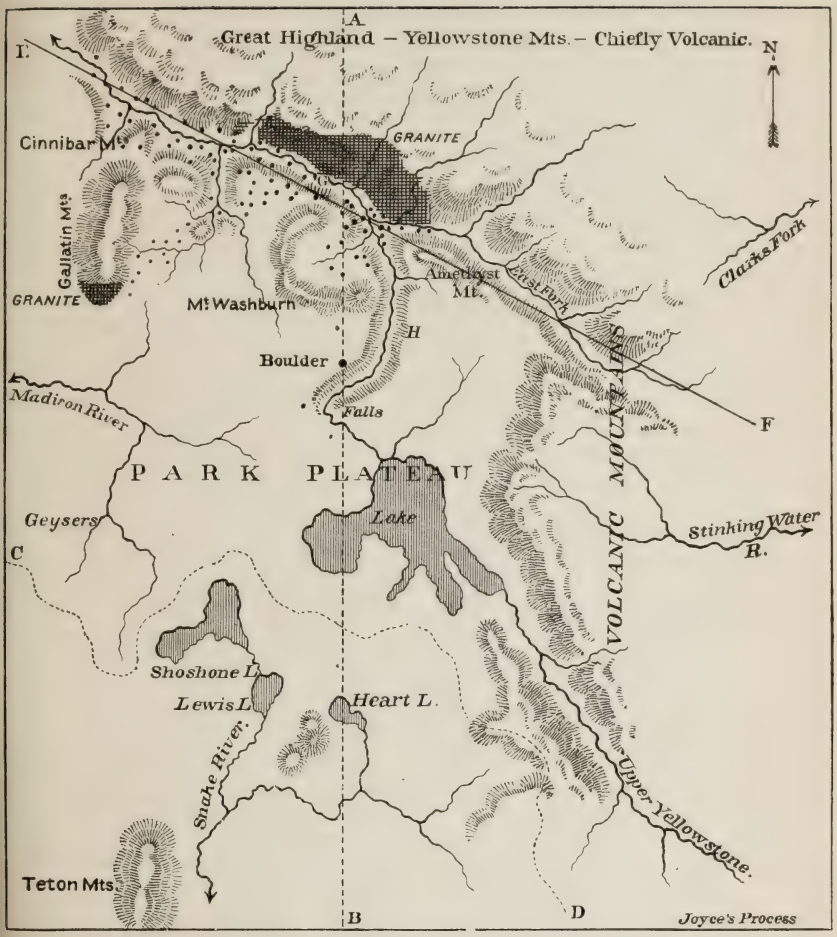
The upper valley of the East Fork has but slight exposures of rock, excepting in the range that encircles it, and is a beautifully diversified upland, which abounds in parks and pine forests. Bands of elk were met with hourly, and the forests were continually resounding with their varied and somewhat extraordinary calls.

GLACIAL PHENOMENA.

In common with very many of the more elevated districts of the Rocky Mountains, the Park district presents a variety of glacial phenomena. In exploring the deep valleys of the higher ranges, the geologist is never surprised at encountering on all hands partially rounded masses of transported rock. These are pretty sure to be found on most of the old flood-planes of the streams and often high up the sides of the valleys. They are frequently the only remaining records of ancient glaciers which have filled the valleys at different stages of their erosion. The glaciation of rocks *in situ*, in the narrow gorges, also bears testimony to the former existence of glaciers. Loose bowlders are doubtless, in many cases, carried from their original beds by the force torrents, and not infrequently reach places very far distant from their original station by a gradual creeping or sliding movement—the result of undermining or yielding of the soil beneath. It is, therefore, far from safe to conclude that wherever erratic rocks are found glaciers have formerly existed, especially in cases where these rocks may have had their origin in surrounding highlands, or even quite distant mountains of very considerable elevation. In a region like this, however, there is every reason to suppose that glaciers once existed on a very extensive scale.

The Park, with the great continental water-shed that surrounds it, forms one of the grandest masses of highland in the United States. In early Quaternary times, as now—if there have been no important changes of level in the mean time—the general level of the Park district exceeded 8,000 feet, and the broad areas of mountainous country on the west, north, and east represent a former general elevation of 12,000 feet or more.

Glaciers exist now in the neighboring Wind River and Teton Mountains at elevations much below 12,000 feet, and in the midst of glacial times descended in immense sheets to 4,000 and 5,000 feet. It would, therefore, be a matter of surprise if traces of glaciers were not found here, not only in the high valleys, but upon the surfaces of the broad plateaus of the Park. There is, however, a singular absence of well defined glacial moraines. The tens of thousands of granite bowlders that occur on both sides of the Yellowstone Valley, from Cinnabar Mountain to the north base of Amethyst Mountain, generally lie upon the smooth surface of the flood planes of the river, or upon low ridges of alluvial drift. The significance of this fact may be that the transporting glaciers existed in the earlier stages of the erosion of the valley, and that the morainal ridges have been destroyed by the river as it oscillated from side to side in the succeeding stages of its descent from the plateau level to its present bed. These great bowlders would, in such a case, be the more durable masses of the moraines stranded on the various flood planes for want of water power to transport them.



A-B, Section line. C-D, Ocean divide. E-F, Line of Great Fault. G, Third cañon. H. Grand cañon. The black dots indicate the position of granite boulders.

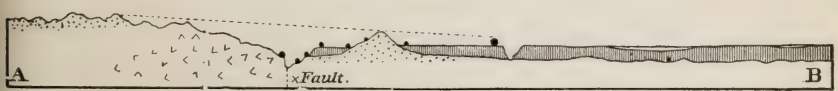


Plate XXX.—Distribution of Glacial Bowlders.

When we come to search for the source of the granite, we are led to observe an interesting fact. The only bodies of granite rock within the limits of this valley are found either on the north side or on the bottom at no considerable elevation above the river. But the erratic masses occur to a great extent on the south side of the valley and at all elevations. In the vicinity of Mount Evarts they reach the upper surface of the plateau more than 2,000 feet above the river bed. It is evident that these masses of granite were transported to their present resting places either before the valley existed or that the ice streams were so deep as to fill the valley to the brim and thus carry and strand them. Still it is a question whether in the latter case these bowlders would ever reach their positions on the south side—supposing the glaciers to follow the course of the valley—as they would have to accomplish the feat of crossing the whole width of the glacier as a boat would cross a ferry. This could really only occur in case there should be such an increase in the masses of ice descending from the highlands to the north as to completely fill the valley, sweep across its course, and overspread the broad table-land to the south. This table-land I have named the Park Plateau; it is wholly volcanic, and is separated from the base of the granite highlands on the north by the valley of the Yellowstone proper, and by the East Fork, its geologic as well as topographic continuation. It extends, with but few interruptions, 100 miles to the south. We are here led to inquire whether or not there are evidences of former glaciers on this plateau. Such evidences do exist, but they are certainly not such as we might expect. Instead of well-defined moraines, an area dotted by erratic bowlders and broad expanses of polished surfaces as in the Wind River and Teton Mountains, we find only a few rocks other than those that may have been derived from the plateau itself. It should be remarked, however, in this connection, that the soft rhyolites which form the greater part of the plateau would not retain glacial markings for any considerable length of time.

An occasional small block of granite indeed is found, and sometimes at unexpected levels, as on the slopes of the Washburn Mountains, many hundreds of feet above the general level of the plateau. A very few have been observed beyond Mount Washburn, on the south side. The most remarkable example of these is a bowlder resting upon the brink of the grand cañon, about a mile and a half below the great falls and nearly eighteen miles from the northern border of the plateau.

On a stormy day in December I undertook to meander the Grand Cañon from the falls to the base of Mount Washburn, and during a storm of rain and sleet took shelter under the overhanging edge of a great rock in the dense timber. Considerably to my surprise I discovered it to be a very compact, coarsely crystalline feldspathic granite. In shape it is somewhat rectangular, the edges for the most part sharp and unworn, the result of spawling by the heat of forest fires. In cubical dimensions it will probably exceed 2,000 feet. It is within a stone's throw of the brink of the cañon and rests upon a sheet or a series of sheets of rhyolite, not less than one thousand feet in thickness, as may easily be determined by an examination of the section exposed in the cañon walls below.

In seeking the possible source of this rock, we naturally turn to the south, towards the sources of the Yellowstone. The plateau alone the river's course and around the lake is totally volcanic. The great ranges to the east and south of the lake are not known to contain a single ex-

posure of granitic rock. That there are no such formations in the whole drainage of the Upper Yellowstone is established by the fact of the almost total absence of granite pebbles on the shores of the lake or in the bed of the river. The home of this wanderer must be sought elsewhere. To the north, beyond the valley of the third cañon and the East Fork, lies the granite highland previously mentioned. To the northwest, beyond the valley of Gardiner River, at the southern end of the Gallatin Mountains, is another exposure of granite at an elevation sufficient to have given origin to it. The distance in either case is upwards of 20 miles. From the great falls the river descends in a northerly direction until it strikes the base of the granite highland; here it unites with the East Fork and turns to the west along the south base of that highland, following the line of the great displacement, until it passes the granite gateway of the second cañon (see map, plate XXX). To reach its present position from the northern locality, the bowlder must cross the course of the great valley of the East Fork and the third cañon and ascend the river, as it now exists, a distance of 20 miles, avoiding on its way, by a circuitous route, the intervening Washburn Range and the opposing mass of Amethyst Mountain. If from the Gallatin Mountains, it must first have crossed the valley of the Upper Gardiner River and afterward a considerable spur of the Washburn Mountains—a journey of 20 miles southeast. Notwithstanding the fact that this pathway would, with anything like the present topography, seem to present fewer obstacles to the advance of a glacier than that from the north, I cannot regard it as at all probable that this was its course. The mass of the Gallatin Mountains is not great. Glaciers originating in its short abrupt valleys would have no great longitudinal extent, and would probably advance no farther than the deepest part of the valley that lies along its immediate base.

The great ranges to the north are of sufficient extent to give birth to ice rivers of the grandest proportions. The present distribution of the erratic fragments of granite tends to strengthen the impression that they had their origin in the north. If this be admitted, it becomes at once clear that the erosion of the Grand Cañon has been accomplished since the close of the glacial period, or at least that a second erosion has taken place if a cañon did exist prior to the glacial epoch.

That a very profound erosion had taken place along the course of the cañon at a very early date is proved by the fact that during the rhyolitic period as well as the basaltic and andesitic, there were cañons almost as deep as the present one, into which the coulées cascaded. At one spot near the northern base of Mount Washburn the section of a fossil river is exposed more than half way down the cañon wall, the bed of which has been cast in andesitic lava, and the volume of whose water discharge is recorded in pumice stone.

These events probably belong, however, to Miocene and Pliocene times, and the topography of this region in those periods—the course of the rivers and the configuration of the country must for the most part remain unknown.

Topographic changes of Quaternary times are, however, much more easily traced. The mass of glacial ice necessary to carry the great bowlder described above to its present resting place would change the whole drainage of the Park. The waters of the Upper Yellowstone and of the numerous tributaries of the lake would be forced across the low continental divide to the south and become tributary to Snake River and the Pacific, or otherwise to some of the western branches of the Missouri.

Thus far I have spoken of the granite bowlders only. I do not imagine that these give anything like a full record of the glacial work accomplished in this region. There are indications of glaciation on a grand scale in which the volcanic rocks alone were involved. In order to get at this matter in a comprehensive way, let us go back to the beginning of Quaternary times; let us try to determine the configuration of the country before the ice had begun its work. The last great event of the Pliocene age was the accumulation of a great series of stratified conglomerates—the greatest of all the wonders of this unique region. The remnants of these formations are found distributed over an area of nearly 10,000 square miles, and occur in such a manner as to lead us to believe that they were formerly continuous over a large part of this area. That they are of Pliocene age is proved by the plentiful occurrence of the vegetable remains of that age.

The fact that this great series of formations could be laid down in moderately well distributed strata from the bottoms of the lowest valleys to the summits of the loftiest peaks, without inclosing, so far as observed, a single granite fragment, is sufficient proof that the granitic rocks could only have formed the sub-strata of the country in Pliocene times.

At the beginning of the glacial period, therefore, the surface of the Park district must have been almost exclusively volcanic. The ice streams would encounter no other than volcanic rocks, and the record of the earlier part of the glacial work must be looked for in the volcanic rocks and in the volcanic drift of the glaciated district.

It takes no great effort of the imagination to picture the whole Park Plateau covered with a mass of snow and ice—a great *nevé* field fed by the accumulating snows from the surrounding highland, and extending its numerous ice tongues far out to the south and west, forcing them across the ocean divide into the Snake River Valley, or into the headwaters of the Missouri.

A dense forest now covers the whole region, and the deposits of glacial drift are hidden from the observer.

The geologic formations are of a character not fitted to retain the striations and the polishing accomplished by the ice.

The only result remaining to bear witness to the great events of that time is a fine group of lakes now resting in the center of the plateau.

YELLOWSTONE LAKE.

I may not be able to find good evidence that these lakes are of glacial origin, for who can say that they do not occupy basins of subsidence, or basins resulting from the building up of a rim by deposits of lava.

In reference to these two points, it may be remarked that no evidences of subsidences or displacements have been observed about the shores of these lakes, besides their very irregular outline and their long arms reaching out in all directions make it difficult to believe that their basins are areas of subsidence.

In regard to the building up of the rims of the basins and the filling up of outlets by streams of lava, it may be answered that so far as we know the rhyolites which form nearly the whole of the lake shore were deposited long antecedent to the period of erosion and glaciation which witnessed the modeling and remodeling of the face of the whole country.

The rhyolite lavas are probably Miocene and Pliocene, and the basin into which they flowed may or may not have contained a lake or lakes.

Such exposures of the bottoms of the flows as occur at the north show

that the flow did not occur in a lake, but in a deeply eroded surface of dry land.

The present Yellowstone Lake is so well known as to need no extended description here. Its shores are generally flat and timber-covered, meadows occurring at rare intervals. The only mountains that approach it so closely as to give it their drainage are the Yellowstone Mountains to to the east; even these do not rise directly from its shores, but stand back from 5 to 10 miles.

A good idea of the character of the surrounding country may be had by observing that if the waters of the lake were raised 200 feet the water surface would be more than doubled. The history of the lake has not yet received the attention its importance demands. The great extent of the deposits of the ancient lake are dwelt upon at length by Dr. Hayden in the reports for 1871 and 1872.

My own observations tend to show that his estimates of the thickness of the deposits and of the elevation of the old shore-line are too great and contrary to what he surmised, and to what any observer might be led to suppose, the ancient lake expanded to the north and east considerably more than to the south and west, where the country seems open through to the broad plateaus of the Pacific Slope. My own observations in the southwest are, however, by no means satisfactory.

In Plate (XXXI) 4 I present a sketch of the Yellowstone Lakes, ancient and modern, the shore-line of the ancient lake being defined as far as possible by the actual occurrences of its deposits. Where these deposits have been removed by subsequent erosion, the outline is continued along the contour which represents the ancient lake level.

The level of the present lake, as determined by the most recent observations, is 7,738 feet. Among the many barometric observations made on the highest levels of the lake deposits there is no single one which reaches 300 feet above the present lake, the highest record being made at a point near the Howard road, some 8 or 9 miles west of the Mud Geyser. This, by aneroid, is 8,028 feet.

On Pelican Creek the highest terrace has a general level of 7,950 feet. On the eastern shore of the lake, and so far as I have observed on the south, the highest terraces are not over 100 feet above the present lake. It is possible that higher levels exist. The heavy growth of forest makes it very difficult to trace beach-lines that might otherwise be followed with the greatest ease.

The most extensive deposits occur in the valley of Pelican Creek and in Hayden's Valley. The region occupied by the Pelican Creek deposits was formerly a wide bay of the ancient lake. The deposits consist of coarse sandstones and conglomerates, both of which seem to have been greatly altered by solfataric action. The series of fine terraces bordering Pelican Creek are probably in some cases river terraces.

The western shore of the ancient lake has not differed greatly from that of the present lake, but on the south its waters have probably covered a very extended area.

Promontory Point existed as an island, but most of the flat tongues of land separating the arms were covered by the waters of the old lake.

The low divide that seperates the waters of the Yellowstone from the Snake River drainage is from 2 to 10 miles from the lake shore and must have been almost on a level with the ancient lake.

There are no indications, however, that the lake ever had an outlet in this direction, although one is at a loss to see why such a large part of the drainage of the rhyolite plateau should cut its way through the great metamorphic range to the north, when the divide to the south and west presents such inconsiderable barriers.

MAP OF
YELLOWSTONE LAKE
SHOWING THE DIMENSIONS
OF THE
ANCIENT LAKE

Plate XXXI.

At present the only view that can be taken is that before the flow of the rhyolite a passage-way had been cut through the northern ranges, and that the flows of lava were such as to sustain the old divide or build up a ridge of sufficient height to create a new one at the present place. Such is the character of the great divide district, even after a great period of erosion in which enormous valleys have been cut, that a flow of lava 300 feet thick, into the Yellowstone Valley at any point above the falls, would turn the drainage of the whole lake district, together with that of the Upper Yellowstone Valley, into the valley of the Snake.

It is easy to see, therefore, what a diversified succession of events may have taken place in the drainage of the Park Plateau during the volcanic period, as very slight flows of lava might have kept the drainage of many thousand square miles balancing between the Atlantic and Pacific.

It seems probable, however, that since the close of the rhyolite producing period there has been but little change except that of the deepening of the drainage by erosion. The greatest changes effected by this agency being the carving of the cañon and the draining of the ancient lake. An important area of the ancient lake has been completely drained. It occupied the depression now known as Hayden's Valley.

On the north this arm extended almost to the immediate base of Mount Washburn. The accompanying map, Plate (XXXI), gives an approximation to the outline of the ancient lake.

PETROGRAPHIC NOTES ON THE VOLCANIC ROCKS OF THE YELLOWSTONE PARK.

By Capt. C. E. Dutton.

Washington, D. C., *July* 3, 1879.

Mr. W. H. Holmes:

My Dear Sir: I have examined the volcanic rocks you collected in the Yellowstone Park and vicinity, and they are very interesting. The rhyolites especially present an attractive study. They are all of the most typical kind, being hyaline or vitreous, and abounding in those characters which are associated or even correlated with the most siliceous eruptive rocks. I understand from you that this series of rocks comes partly from massive sheets of ancient lava and partly from volcanic conglomerates. Those from the former sources are rhyolites and basalts; those from the latter are chiefly hornblendic andesites with a few hornblendic trachytes. The former are much younger than the latter and agree as to their time relations with the general laws of succession of eruptions prevailing throughout the mountain regions of the West. As to the geological relations of these rocks, I am unable to say anything, being insufficiently apprised of the observed facts.

There is one feature which seems to be shared by pretty nearly all these rocks, and that is the great amount of alteration which they have undergone since their extravasation. The alterations are not only extensive but are somewhat peculiar. It is most conspicuous in the hornblendes, which have been altered, not, as more frequently happens, into viridite or magnetite, but into peroxide of iron, which has the facies of hematite rather than limonite. This alteration, however, generally

affects the surfaces of the hornblende crystals more than the interior, and where a crystal so altered is exposed by fracture it might readily be taken for a pseudomorph of hematite or limonite after hornblende. A section through the crystal, however, generally discloses a core of unaltered or only partially changed hornblende. In the cases of smaller crystals or hornblendic dust and microlites, the alteration is often complete and the color of the groundmass is changed from the normal dark gray or green of hornblende andesite to a light yet strong red. In the fine-grained varieties this has produced a strongly deceptive appearance, and any one familiar with volcanic rocks would have been led after macroscopic inspection to pronounce such rocks either acid trachytes or even rhyolites. The thin sections, however, show abundant plagioclase and very little sanidin; they also reveal abundant traces of the dissolution of the hornblende. The cause of this extensive alteration may possibly be found in the action of hot-spring waters so abundant throughout this district. It appears to be decidedly different in its effects from the ordinary action of atmospheric waters.

I give herewith a diagnosis of the various specimens:

No. 1. RHYOLITE.

This specimen contains a very few small crystals of sanidin and still fewer and smaller quartzes, disseminated in a hyaline or perlitic base, showing indistinct fluidal texture. The field is occasionally traversed by lines or seams which appear to be almost pure quartzite; also spots or miculi of the same. There is considerable ferritic matter disseminated throughout the base, imparting a pale reddish color. A few dark brown spots occur, which may be decomposing hornblende.

Locality.—Eastern spur of Sepulchre Mountain, about one mile above Mammoth Hot Springs.

No. 2. RHYOLITE.

Contains very few fragmental crystals of sanidin and quartz, the quantity of crystaline matter being quite small. The base has very strongly marked fluidal characteristics, and exhibits figures which are axiolitic (very similar to that given by Zirkel in Fig. 1, Plate VI, Survey Fortieth Parallel, Vol. VI).

Locality.—Summit of Mount Evarts, opposite Mammoth Hot Springs.

No. 3. RHYOLITE.

An extremely fluidal base, showing a web of coarse, glassy fibers, forming tangled meshes without any definite direction. Base wholly glassy. Crystals very few and very minute, chiefly sanidin, with curious inclusions of long, slender needles of feldspar.

Locality.—Base of sheet capping Mount Evarts.

No. 4. RHYOLITE.

Shows a mottled or damosene base, which is axiolitic. Crystals few and fragmentary. Several plagioclase crystals noted.

Locality.—Low hill to the left of Elk Creek crossing, Junction Valley.

No. 5. RHYOLITE.

Holding fragmental and distorted crystals of quartz and sanidin; scanty and small. The base shows the fluidal structure to an extreme degree, in very irregular forms, however, as fibrous or drawn out in the direction of flow in wavy lines, consisting of a thoroughly transparent glass surrounded by a border of nearly opaque glass, probably charged with ferrite. Whenever this peculiar groundmass borders upon a crys-

tal it takes the ordinary eye-form. The crystals seem to be bent as if they had been viscous or nearly fused during the flow.

Locality.—Wall of Yellowstone Cañon, south side, 5 miles above Tower Falls.

No. 6. RHYOLITE.

Indistinctly spherulitic base. There are no distinct crystals.

Locality.—Same as preceding.

No. 7. RHYOLITE.

Locality.—Same as preceding.

No. 8. RHYOLITE.

Showing a few crystals of quartz and sanidin, both containing very numerous and fine glass inclusions, which are in some cases double. The base of the rock is one of the most extraordinary I have ever seen, presenting a very remarkable form of globulitic devitrification (see Zirkel, Survey Fortieth Parallel, Vol VI, last figure). The groundmass is densely charged with spherulites, which are closely appressed and in actual contact. They show radial fibers, radiating from centers which polarize well, and are evidently crystalline; and between crossed nicols a dark cross is formed by the intersection of two planes of extinction in the center of each globulite. The radial fibers are too minute to be individually recognized, but are evidently thoroughly crystalline, for as the nicols are rotated opalescent colors are formed which rotate around the center of each globule like the four arms of a windmill.

Locality.—Near the Mud-puffs, Lower Geyser Basin.

No. 9. RHYOLITE.

Has a white opaque base containing a great abundance of rounded and fragmental quartz crystals; feldspars extremely rare.

Locality.—Cañon of the Yellowstone, near falls.

No. 10. RHYOLITE.

The base is globulitic and of a most interesting character, showing that the texture is due to the operation of crystallogenic forces. The devitrification of the base commences around a great number of points as centers, and leads to a radial arrangement of the matter in its vicinity, a portion of which is probably definitely crystallized. In some cases this crystallization has proceeded so far that the crystal can be very distinctly recognized, and seen to possess an arrangement similar to that of fine-grained porphyritic granite; but in most cases the crystalline structure can be detected by the polariscope. When the polarizer is rotated four arms of a cross (four brush-like groups of rays) are seen to rotate around the center of each globulite. Thus some portions of the groundmass are wholly crystalline, while other portions are in incipient stages of crystallization.

Locality.—Yellowstone Cañon, foot of the Great Falls.

No. 11. RHYOLITE.

A white, chalky rhyolite. It holds moderately thickly disseminated crystals of quartz, with rounded edges, and usually having either glass inclusions or inclusions consisting of base. There are few crystals of sanidine. The base is quite striking, and rather unusual, though I have before seen instances very similar to it. It is minutely granular, almost uniformly so, with fluidal texture. When seen with a power of 350 diameters, the base has an appearance suggesting that of very fine-grained

quartz porphyry when it is viewed with a very low magnifying power. The amount of aggregate polarization is considerably less than is seen in most of the quartz porphyries.

In the vicinity of some of the quartz crystal the base has a grayish color, forming a grayish band around the crystal. In some instances this grayish band gradually shades into the body of the crystal itself in such a manner that there is no definite boundary, suggesting the possibility that the secretion of the crystal from the base had proceeded from the center or axis outwards, gradually absorbing the base, and converting it into crystalline substance.

Between crossed nicols the groundmass shows many spots which are much brighter than the adjoining portions, while between parallel nicols the same spots are darker than the adjoining portions. These spots obviously contain crystalline matter in some form, and may be incipient crystalloids.

Locality.—Grand Cañon of the Yellowstone, at foot of Great Falls.

No. 12. RHYOLITE.

Contains comparatively few crystals of sanidin, and many small crystals of quartz. Base consists of granular felsite, with decided aggregate polarization. The quartz crystals contain glass cavities. There is no accessory hornblende or mica.

Locality.—Madison Plateau, opposite the junction of Gibbon River with the Madison.

No. 13. RHYOLITE.

Locality.—Mount Sheridan.

No. 14. RHYOLITE.

Locality.—Mount Sheridan.

Nos. 15, 16, and 17. TRACHYTE.

Much altered, probably by solfataric action. Feldspars much decomposed, and do not polarize except occasionally in very small portions of the original crystals, and then only imperfectly. Crystals porphyritic, the base having a fine-grained felsitic character, very nearly amorphous. Fragments of hornblende very much decomposed and largely replaced with hydrated peroxyd of iron.

In the green specimen the hornblende shows the ordinary alteration into viridite and epidote.

Locality.—Junction Valley, near the base of Garnet Hill.

No. 18. PORPHYRITIC TRACHYTE.

This rock has the usual characters common in the laccolite trachytes; very large and beautiful crystals of sanidin, showing less than the usual amount of decomposition; polarizing sharply, many of the larger crystals showing beautiful twins which have the zonal structure. The base is micro-crystalline, and shows a large amount of polarization, approaching to that of some granite porphyries. There is considerable biotite, also grains of magnetite, disseminated throughout the ground mass. Small crystals of plagioclase are present.

Locality.—The great laccolite, Indian Creek, East Gallatin Mountains.

No. 19. HORNBLENDIC TRACHYTE.

Locality.—Summit of Mount Chittenden.

No. 20. PROPYLITE (?)

This specimen has many of the characters of a propylite. It consists of a tolerably homogeneous base, holding crystals of plagioclase and orthoclase and an abundance of what was once probably hornblende, but which has been converted into peroxide of iron. Presuming these to be hornblendes, the mode of their occurrence, their dissemination in fragments of fine dust throughout the base, is quite characteristic of propylite. The larger feldspar crystals are in most cases sanidins, having the zonal structure and often exhibiting Carlsbad twins. The plagioclases are far more numerous, but smaller in size than the sanidins. Very many of them show a curious fibrous structure, as if the crystals were built up of minute microlitic stuffs, and myriads of these swarm throughout the base. Traces of brown hornblende not wholly decomposed are sometimes seen, but ordinarily the characters of the hornblende are past recognition.

Locality.—In breccia, Terrace Point, head of Yellowstone Lake.

No. 21. HORNBLENDIC ANDESITE.

A much altered rock, externally reddish, differing from the hornblende andesites, which are usually bluish, greenish, and grayish; the color is undoubtedly due to weathering or solfataric action. The characteristic color of epidote is seen in macroscopically greenish-yellow spots, which occur abundantly in the groundmass, but do not sensibly affect the reddish tone of the rock itself. Crystals quite small and rare, though the microscope shows great multitudes of small ledge-formed crystals of triclinic feldspar and a great abundance of two varieties of hornblende, dark brown and pale green, the latter being very strongly dichroitic, the former moderately so. The brown hornblendes have the characteristic black shaded border, which is seldom wanting in the hornblende andesites. Green stains, arising doubtless from the decomposition of hornblende, are abundant throughout the base. There are many feldspar microlites. The base is for the most part amorphous.

Locality.—Crossing of Beaver-dam Creek, near head of Yellowstone Lake, in breccia.

No. 22. HORNBLENDE ANDESITE.

Differing notably from the one just described, containing, however, a large number of similar plagioclase crystals, many of which seem to be broken and shattered transversely. There is much microfelsitic matter desseminated throughout the base, which polarizes considerably. The hornblende seems to be confined to crystals of notable size. There is an absence of minute hornblende dust disseminated throughout the base. The rock is, therefore, grayish rather than green. The large hornblendes have characteristic black shaded borders. They polarize splendidly and are strongly dichroitic.

Locality.—Summit of Mount Chittenden.

No. 23. HORNBLENDE ANDESITE.

Closely approximating No. 21.

Locality.—Summit of Mount Chittenden.

No. 24. HORNBLENDE ANDESITE.

Locality.—Summit of Mount Chittenden.

No. 25. HORNBLENDE ANDESITE.

This is almost wholly a feldspathic rock, much altered by weathering; base highly charged with microlites, which must be plagioclase; larger

plagioclase crystals are much decayed; most of the hornblendes have disappeared; a few sanidins can be detected, but have lost most of their polarizing powers.

Locality.—Summit of Grizzly Peak.

No. 26. HORNBLENDE ANDESITE.

Locality.—Tower Falls, in breccia.

No. 27. AUGITE ANDESITE.

Groundmass consists of small plagioclase crystals and many feldspar microlites, disseminated throughout the base, which show a very large amount of aggregate polarization. The base is exceedingly fine grained, and between crossed nicols is so full of luminous points, which yet cannot be distinctly recognized as possessing definite crystalline form, that the diabase is suggested. On the whole, however, there is probably present a considerable amount of amorphous base.

Locality.—Yellowstone Cañon, south side, 5 miles above Lower Falls.

No. 28. HORNBLENDE ANDESITE.

Locality.—Northwest spur of Mount Washburn, in breccia.

No. 29. BASALT.

Has very large crystals of beautifully-striated triclinic feldspar, the lines of striation being wonderfully minute in some of the crystals. Small grains of olivine are tolerably numerous, some of which have been much altered. A few curious crystals of augite and large quantities of amorphous augite are disseminated throughout the mass.

Locality.—Junction Valley, Elk Creek Meadows.

No. 30. DIABASE.

Locality.—Gardiner River, above junction of East Fork.

U.S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES, F.V. HAYDEN IN CHARGE

PANORAMIC VIEWS.

THE EAST GALLATIN RANGE FROM THE SOUTH EAST

WITH THE GIBBON GEYSER BASIN IN THE FOREGROUND

YELLOWSTONE RIVER FROM SEPULCHRE Mt

LOOKING DOWN

VOLCANIC TERTIARY MOUNTAINS

Mt EVARTS FROM MAMMOTH HOT SPRINGS

THE THERMAL SPRINGS OF YELLOWSTONE NATIONAL PARK.

By A. C. Peale, M. D.

Schuylkill Haven, Pa., *August* 1, 1881.

Sir: I have the honor herewith to submit my report on the Thermal Springs of the Yellowstone National Park. It is based mainly upon the observations made in 1878. We reached the Shoshone Geyser Basin, our first working point, on August 15, 1878, and spent ten days mapping and describing the springs of this interesting area. Our next stopping point was the Upper Geyser Basin of Fire Hole River. Here we had in all eight days between the 26th of August and the 11th of September, having in this time also visited the Heart Lake Springs and those of Lewis Lake. We next mapped the Gibbon Geyser Basin in a little over a day and a half. We then worked up the Mammoth Hot Springs of Gardiner's River, leaving them about September 21 to follow up the Yellowstone River and examine the various spring localities along its course.

On October 1 we began work in the Lower Geyser Basin of the Fire Hole River, and finished October 10. We were therefore in the Park within a few days of two months. A considerable portion of this time was spent in traveling from point to point, the spring areas being separated by distances which will be appreciated by a reference to the map of the Park. A large portion of the writer's time was necessarily devoted to topographical work in assisting Mr. J. E. Mushback, to whose fidelity and zeal is due the fact that the accompanying maps of the various Geyser Basins are presented. The writer's thanks are also due to Mr. H. Gannett, Mr. W. H. Holmes, and Mr. F. E. Owen for the preparation of maps and illustrations.

The accompanying report is divided into three parts.

Part I is devoted to the description of the spring areas according to their location on the systems of drainage that lie within the Park.

In Part II I have given short descriptions of the principal geyser regions of the world for the sake of comparison with our own, and also because the remarks in the portions of the report following are partly based on observations made in other geyser regions than our own. I have also added brief chapters on the Thermal Springs of the United States and other parts of the world, incorporating catalogues of the same, which are as complete as the time at our command permitted us to make them.

In Part III, as a reference to the table of contents will show, I have considered briefly the points of a more general nature in relation to hot springs and geysers. I have been obliged to present them in a somewhat incomplete state, owing to the fact that our organization was disbanded before even this portion of the report was begun. This fact, with the removal from a general office and from as free access to the libraries as is desirable, with the cares of business since the breaking

up of the survey, have precluded the completion of the report in f according to the original plan.

The chemical work, for which I am indebted to Dr. Henry Leffman owing to the limited amount of money devoted to it, is not as comp hensive as wished, and the experiments as to the cause of the color the waters of the springs of the Park have only been commenced. present the results of the experiments as far as they have been carri A bibliographical appendix is added, containing the bibliography of t the Yellowstone National Park, Iceland, and New Zealand, and therm springs in general. These have been made as complete as possib although they are not exhaustive.

But few references to the geology of the Park have been made, as t report of Mr. W. H. Holmes will present it in detail. All topographi details will be found in Mr. Henry Gannett's report, and I have the fore merely given the situation of the springs.

Hoping this report may prove satisfactory, I remain, with great spect, your obedient servant,

A. C. PEALE

Dr. F. V. HAYDEN,
United States Geological and Geographical Survey of the Territories.

PART I.

DESCRIPTIVE OF SPRINGS AND GEYSERS OF YELLOWSTONE NATIONAL PARK.

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INTRODUCTION.

The Yellowstone National Park (or reservation, as it may perhaps be more correctly termed) lies mainly in the northwestern corner of Wyoming, extending on the north and west into the Territories of Montana and Idaho, which are adjacent. It is 55 miles by 65 miles, and includes, therefore, 3,575 square miles or 2,288,000 acres. In connection with this large area, the name "park" is perhaps misleading, as it is exceedingly diversified, containing numerous parks, or open spaces, high mountain ranges, and beautiful lakes. The name is not used in the way it is in Colorado, meaning immense valleys or basins of approximately level country, but is more nearly synonymous with "reservation" in this place.

John Colter or Coulter was probably the first white man who ever saw any of the springs or geysers of this wonderful region. He was connected with Lewis and Clarke's expedition, and on their return, in 1806, left the expedition to go back to the headwaters of the Missouri to trap and hunt. After a narrow escape from the Blackfeet Indians, he lived for some time with the Bannock Indians, who ranged through the country in which the Park is located. In 1810 he returned to Saint Louis and told wonderful tales of the region, which were not believed. "Coulter's Hell" was the term afterwards applied to the region by hunters and

trappers, who had heard of it from him, but had never been there. As far back as 1844, James Bridger, one of the best and most noted of Rocky Mountain guides, is said to have described some of the wonderful springs and geysers, but his stories were supposed to be made out of the whole cloth, and although it is said he endeavored to get some of the western newspaper men to publish some of his tales, they were so marvelous that no one would do it.

In Capt. John Mullan's report on the construction of a military road from Fort Walla Walla to Fort Benton occurs the following mention of geysers. He says:

> As early as the winter of 1853, which I spent in these mountains, my attention was called to the mild open region lying between the Deer Lodge Valley and Fort Laramie. * * * Upon investigating the peculiarities of the country I learned from the Indians, and afterwards confirmed by my own explorations, the fact of the existence of an infinite number of hot springs at the headwaters of the Missouri, Columbia, and Yellowstone Rivers, and that hot geysers, similar to those of California, existed at the head of the Yellowstone; that this line of hot springs was traced to the Big Horn, &c.

On page 10 of Captain Raynolds's report on the exploration of the Yellowstone River* is the following paragraph:

> Beyond these [referring to Pryor's River, Clark's Fork, Big Rosebud, and Beaver River] is the valley of the Upper Yellowstone, which is as yet a *terra incognita*. My expedition passed entirely around, but could not penetrate it. My intention was to enter it from the head of Wind River, but the basaltic ridge previously spoken of intercepted our route and prohibited the attempt. After this obstacle had thus forced us over on the western slope of the Rocky Mountains, an effort was made to recross and reach the district in question; but although it was June, the immense body of snow baffled all our exertions, and we were compelled to content ourselves with listening to marvelous tales of burning plains, immense lakes, and boiling springs, without being able to verify these wonders. I know of but two white men who claim to have ever visited this part of the Yellowstone Valley—James Bridger and Robert Meldrum. The narratives of both these men are very remarkable, and Bridger, in one of his recitals, described an immense boiling spring that is a perfect counterpart of the geysers of Iceland. As he is uneducated, and had probably never heard of the existence of such natural marvels elsewhere, I have little doubt that he spoke of that which he had actually seen.

This is probably the first printed reference to the springs and geysers of the Park, although there were floating traditions among the early trappers and hunters.

In 1863 a party of prospectors, of which Capt. Walter W. De Lacey was one, ascended the Snake River, and from Shoshone Lake (which was named De Lacey's Lake afterwards by General Meredith, surveyor general of Montana) crossed to the Lower Geyser Basin, one branch of the party having visited the springs and geysers of the Shoshone Geyser Basin. No description of the Shoshone Geysers was published by them. Captain De Lacey, writing of the Lower Geyser Basin in the paper by him published in the "Contributions to the Historical Society of Montana," says they reached the valley on the 9th of September, 1863 (see page 132). He does not give any description of the various springs. In the following years many prospectors visited portions of the Park, the Botteler Brothers, C. J. Barronette, and Bart Henderson being among them. In 1869 Messrs. Cook and David E. Folsom visited the region, and the account of their trip, published in the Lakeside Monthly, of Chicago, is probably the first authentic *description* ever published of these springs and geysers outside of brief accounts in the local papers.

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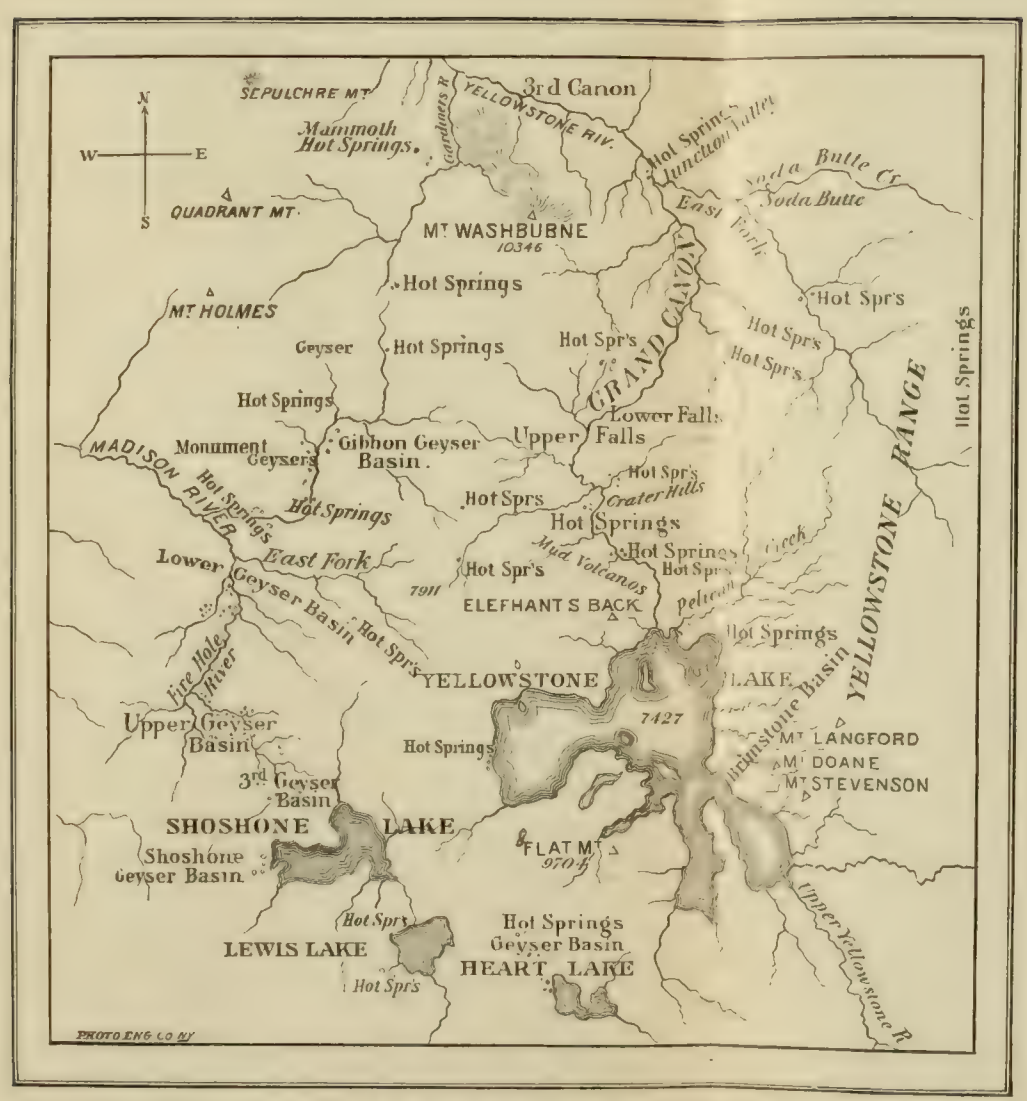
* Senate Executive Document No. 77, Fortieth Congress, first session. Report of the Secretary of War, communicating, &c., * * * the report of Bvt. Brig. Gen. W. F. Raynolds, &c.



Map of Yellowstone National Park, showing distribution of Hot Springs.

of Montana. Mr. N. P. Langford, formerly superintendent of the Park, in a private letter to the writer says:

> An account of their expedition was written by David E. Folsom himself, and his partner (Cook) sent it to his brother for perusal, and it seemed so wonderful that the proprietors of the Lakeside Monthly, of Chicago, published it in May or June, 1870. Not knowing who the author was, the publishers gave the name of Mr. Cook as the author. Mr. Cook was much chagrined by this blunder, which deprived Mr. Folsom of the honor due him, and did all he could to set the matter right.

In Raymond's Mining Statistics West of the Rocky Mountains (Washington, 1870), in the chapter on Gallatin County, Montana, page 312, occurs the following paragraph:

> Parties who have visited this *terra incognita* [Yellowstone Basin] report it replete with grand and wonderful phenomena—crevasses of stupendous depth, petrified forests, plains of lava and brimstone, geysers spouting boiling water fifty to seventy feet high, &c., but their reports are too indefinite to serve for reliable description.

In 1870 the Washburn party explored the region, and two of the members of the party described its wonders in magazine articles published in the spring of 1871. Mr. N. P. Langford's illustrated articles appeared in the May and June numbers of Scribner's Magazine, 1871, and Mr. Walter Trumbull's description in the Overland Monthly, June, 1871. Lieutenant Doane, of the Second Cavalry, who accompanied the Washburn expedition in command of the escort, also made an official report of the trip to General Hancock.

During the summers of 1871 and 1872 the Geological Survey of the Territories made their explorations of the Park, and gave to the world the first scientific account of the region. One of the results of the exploration of 1871 was the setting aside of the region including the various spring areas, as a National Park.

From 1872 to 1878, the time of our third visit, the Park was visited by many parties, and for a further list of publications relating to it the reader is referred to the bibliography appended to this report.

A glance at the map of the Park will show that within its limits we have the principal sources of two of our largest rivers, viz., the Missouri and the Snake River or Lewis' Fork of the Columbia. The largest portion of the Park lies to the eastward of the Continental Divide or water-shed. As to its geology, the reader is referred to the more detailed report of Mr. Holmes. Suffice it to say here that it is mainly volcanic, rhyolitic rocks being spread over its surface, forming immense plateaus in most places. The elevation is such that it is not suited for farming purposes. In 1871 there were several mornings in which the temperature fell below the freezing point. August 1 we had ice one-sixteenth of an inch in thickness in our camp on the East Fork of the Fire Hole River, and on the 10th, on Yellowstone Lake, at sunrise, the thermometer recorded 15½°. In July the six o'clock temperature ranged from 42° to 50°. The noon temperature through the summer ranged from 50° to 78°. We had almost the same weather in 1872. In the last of June, 1872, at Fort Ellis, we had a snow storm which whitened the surface where the day before flowers were in bloom. In 1878 we had snow storms on September 8, 23, and 24, and on October 1, 13, and 14. On the 10th of September the temperature was 23°, on the 23d it was 18°, and on the 26th, 10°. These temperatures were taken early in the morning. Mr. P. W. Norris, in his report for 1878, gives the average temperature at sunrise for July at 57° and for noon at 80°. For August he gives the average at sunrise at 44° and at noon 78°. In September he says it was 39° at sunrise and 61° at noon. The following table, compiled from his

report for 1879 (pp. 24–27), will give the result of his observations for 1879 at the Mammoth Hot Springs:

Month.	Average temperature.			Lowest temperature.	Highest temperature.	Snowy days.
	Sunrise.	Noon.	Sunset.			
	°	°	°	°	°	
June (18 days)	43	70	57	36	80	None.
July	59	80	63	32	88	None.
August	49	74	69	42	86	None.
September	39	60	53	25	78	3
October	22	52	30	20	70	4
November	23	40	31	2	65	13
December (26 days)	12	18	12	.....	46	15
August 1 to 16, on way to Geysers	43	73	54	30	84	2

On the 8th of October there were 2 feet of snow, and during most of the month there was snow on the ground.

The following table is compiled from the record of temperatures taken during 1880 at the Mammoth Hot Springs by one of Superintendent Norris's assistants (see his report for 1880, pp. 52–57):

Table of temperatures of air, Mammoth Hot Springs.

Month.	Average temperature.			Lowest temperature.	Highest temperature.
	Sunrise.	Noon.	Sunset.		
1880.	° F.	° F.	° F.	° F.	° F.
January	18	27	21	−36	46
February	12	28	18	−16	37
March	13	30	22	−40	46
July	50	68	62	41	92
August	50	68	64	35	85
September	41	66	58	30	80
October	32	57	42	14	80
November	5	24	17	−22	56
December	16	25	20	−26	50

On the 13th of March the mercury froze. On January 29 the thermometer fell 26° in one-half of an hour.

Mr. Walter Trumbull, in his article in the Overland Monthly (vol. vi, p. 495), says:

> As an agricultural country I was not favorably impressed with the great Yellowstone Basin, but its brimstone resources are ample for all the match-makers of the world. A snow storm in September, 2 feet deep, is hardly conducive to any kind of agricultural enterprise or stock-raising.

At a ranch on the Yellowstone, below the mouth of Gardiner's River, there was a garden and potatoes were successfully raised in 1878. This is just beyond the limits of the Park, and the elevation is below 5,500 feet; but even here gardening is precarious. Although frosty nights are the rule in the Park, the cold is less severely felt than in the East, probably because of the extreme dryness of the atmosphere. A temperature of 15° or 20° does not cause as much discomfort as 40° in the East, where there is so much more moisture in the air.

As to the scenery of the Park, a few words are all that will be necessary here. The various picturesque views in the Park have so often been illustrated and its wonderful scenery so often described that a repetition here is needless. As the vivid coloring of the walls of the Grand Cañon of the Yellowstone has been often questioned by those who have never visited the region, I will quote a description of its coloring from

FIG. 1.—Basins at Mammoth Hot Springs of Gardiner's River.

the article of one of Philadelphia's distinguished physicians (doctors are not much given to sentimentality):

The man whose love of color is not satisfied by the view down this marvelous valley must indeed be hard to please. For a mile away the sides are formed of slopes, from which rise vast battlements, turrets, pinnacles, alone or in clusters, of tall, conical spires; some are of basalt, some of limestone [?]; they rise through slopes part clay and part broken silicates and limestone. On this mass of material Nature has lavished her wealth of colors with a spendthrift hand. The taller rocks of ruddy browns or Pompeian red melt away in the débris from which they spring to rich yellows, fading below to cool grays in exquisite gradation. Here and there are rocks of a red-like claret-lees; others have a basis of rich ocher, with the projections of umber-brown. In places the reds are nearly of a dark scarlet. Here, the rocks are of a lovely French gray; there, of a delicate fawn tint, rising above to saffron and melting to snow-white below, while in places patches of vivid green, orange, or black mark the masses of moss and lichen, fed by the abundant spray, and forced into luxury of growth by the warm streams from the numberless springs issuing from the walls of the cañon.*

The view of this cañon is one that never disappoints, and if the visits to the Grand Falls are separated by a few years each succeeding visit only serves to strengthen and heighten the impressions of the first visit, for the coloring is on such a grand scale that it is impossible to retain the memory of its vividness.

The reports of 1871 and 1872 and the various newspaper and magazine articles will give the reader any further descriptions of the scenery, as the space at the writer's command will not permit of any extended descriptions in this report.

As has already been stated, the setting aside of the area now known as the Yellowstone National Park was one of the results of the survey of 1871, and it may be stated that the movement was started by Dr. F. V. Hayden, and its success was mainly due to his personal efforts.

On the 18th of December, 1871, the bill to set apart this tract was introduced into the United States Senate by Hon. S. C. Pomeroy, and about the same time a similar bill was offered in the House of Representatives. The bill was referred to the Committees on Public Lands by both houses and reported upon favorably. In the Senate there was some discussion, the bill being opposed by Mr. Cole, of California, and advocated by Messrs. Pomeroy, Edmunds, Trumbull, Anthony, and others. Mr. Trumbull, in reply to Mr. Cole's objections, made the following argument in favor of the bill:

I think our experience with the wonderful natural curiosity, if I may so call it, in the Senator's own State should admonish us of the propriety of passing such a bill as this. There is the wonderful Yosemite Valley, which one or two persons are claiming by virtue of a pre-emption. Here is a region of country away up in the Rocky Mountains, where there are the most wonderful geysers on the face of the earth—a country that is not likely ever to be inhabited for the purpose of agriculture, but it is possible that some person may go there and plant himself across the only path that leads to these wonders and charge every man that passes along between the gorges of these mountains a fee of a dollar or five dollars. He may place an obstruction there, and toll may be gathered from every person who goes to see these wonders of creation. Now this tract of land is uninhabited; nobody lives there; it was never trod by civilized man until within a short period. Perhaps a year or two ago was the first time that this country was ever explored by anybody. It is now proposed, while it is in this condition, to reserve it from sale and occupation in this way. Now, before there is any dispute as to this wonderful country, I hope we shall except it from the general position of public lands, and reserve it to the government. At some future time, if we do so, we can repeal this law, if it is in anybody's way, but now I think it is a very appropriate bill to pass.

After this the bill passed.

Notwithstanding the fact that the bill was passed so soon after the explorations, there were claimants for certain portions of the Park. J. C. McCartney and Mr. Hore claimed the Mammoth Hot Springs, and

*Lippincott's Magazine, vol. XXV, No. 150, June, 1880, p. 699.

had erected some buildings there before the Park was reserved. C. J. Barronette also had constructed a bridge across the East Fork of the Yellowstone. This bridge was destroyed by the Nez Perce Indians in their raid across the Park in 1877.

The following is the report of the House Committee on the Public Lands:

THE YELLOWSTONE PARK.

Mr. DUNNELL, from the Committee on the Public Lands, made the following report:

The Committee on the Public Lands, having had under consideration bill H. R. 764, would report as follows:

The bill now before Congress has for its object the withdrawal from settlement, occupancy, or sale, under the laws of the United States, a tract of land 55 by 65 miles, about the sources of the Yellowstone and Missouri Rivers, and dedicates and sets it apart as a great national park or pleasure-ground for the benefit and enjoyment of the people. The entire area comprised within the limits of the reservation contemplated in this bill is not susceptible of cultivation with any degree of certainty, and the winters would be too severe for stock-raising. Whenever the altitude of the mountain districts exceeds 6,000 feet above tide-water, their settlement becomes problematical unless there are valuable mines to attract people. The entire area within the limits of the proposed reservation is over 6,000 feet in altitude, and the Yellowstone Lake, which occupies an area 15 by 22 or 330 square miles, is 7,427. The ranges of mountains that hem the valleys in on every side rise to the height of 10,000 and 12,000 feet, and are covered with snow all the year. These mountains are all of volcanic origin, and it is not probable that any mines or minerals of value will ever be found there. During the months of June, July, and August the climate is pure and most invigorating, with scarcely any rain or storms of any kind; but the thermometer frequently sinks as low as 26°. There is frost every month of the year. This whole region was, in comparatively modern geological times, the scene of the most wonderful volcanic activity of any portion of our country. The hot springs and the geysers represent the last stages—the vents or escape-pipes—of these remarkable volcanic manifestations of the internal forces. All these springs are adorned with decorations more beautiful than human art ever conceived, and which have required thousands of years for the cunning hand of Nature to form. Persons are now waiting for the spring to open to enter in and take possession of these remarkable curiosities, to make merchandise of these beautiful specimens, to fence in these rare wonders, so as to charge visitors a fee, as is now done at Niagara Falls, for the sight of that which ought to be as free as the air or water.

In a few years this region will be a place of resort for all classes of people from all portions of the world. The geysers of Iceland, which have been objects of interest for the scientific men and travelers of the entire world, sink into insignificance in comparison with the hot springs of the Yellowstone and Fire-Hole Basins. As a place of resort for invalids, it will not be excelled by any portion of the world. If this bill fails to become a law this session, the vandals who are now waiting to enter into this wonderland will, in a single season, despoil beyond recovery these remarkable curiosities, which have required all the cunning skill of Nature thousands of years to prepare.

We have already shown that no portion of this tract can ever be made available for agricultural or mining purposes. Even if the altitude and the climate would permit the country to be made available, not over fifty square miles of the entire area could ever be settled. The valleys are all narrow, hemmed in by high, volcanic mountains, like gigantic walls.

The withdrawal of this tract, therefore, from sale or settlement takes nothing from the value of the public domain, and is no pecuniary loss to the government, but will be regarded by the entire civilized world as a step of progress and an honor to Congress and the nation.

DEPARTMENT OF THE INTERIOR,
Washington, D. C., January 29, 1872.

Sir: I have the honor to acknowledge the receipt of your communication of the 27th instant, relative to the bill now pending in the House of Representatives dedicating that tract of country known as the Yellowstone Valley as a national park.

I hand you herewith the report of Dr. F. V. Hayden, United States geologist, relative to said proposed reservation, and have only to add that I fully concur in his recommendations, and trust that the bill referred to may speedily become a law.

Very respectfully, your obedient servant,

C. DELANO,
Secretary.

Hon. M. H. DUNNELL,
House of Representatives.

The committee, therefore, recommend the passage of the bill without amendment.

CLEOPATRA SPRING MAMMOTH HOT SPRINGS

LIBERTY CAP AND SHALLOW BASINS. MAMMOTH HOT SPRINGS.

[GENERAL NATURE—No. 16.]

AN ACT to set apart a certain tract of land lying near the headwaters of the Yellowstone River as a public park.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the tract of land in the Territories of Montana and Wyoming, lying near the headwaters of the Yellowstone River, and described as follows, to wit, commencing at the junction of Gardiner's River with the Yellowstone River, and running east to the meridian passing ten miles to the eastward of the most eastern point of Yellowstone Lake; thence south along said meridian to the parallel of latitude passing ten miles south of the most southern point of Yellowstone Lake; thence west along said parallel to the meridian passing fifteen miles west of the most western point of Madison Lake; thence north along said meridian to the latitude of the junction of the Yellowstone and Gardiner's Rivers; thence east to the place of beginning, is hereby reserved and withdrawn from settlement, occupancy, or sale under the laws of the United States, and dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people; and all persons who shall locate or settle upon or occupy the same, or any part thereof, except as hereinafter provided, shall be considered trespassers and removed therefrom.

SEC. 2. That said public park shall be under the exclusive control of the Secretary of the Interior, whose duty it shall be, as soon as practicable, to make and publish such rules and regulations as he may deem necessary or proper for the care and management of the same. Such regulations shall provide for the preservation, from injury or spoliation, of all timber, mineral deposits, natural curiosities, or wonders within said park, and their retention in their natural condition. The Secretary may, in his discretion, grant leases for building purposes for terms not exceeding ten years, of small parcels of ground, at such places in said park as shall require the erection of buildings for the accommodation of visitors; all of the proceeds of said leases, and all other revenues that may be derived from any source connected with said park, to be expended under his direction in the management of the same, and the construction of roads and bridle-paths therein. He shall provide against the wanton destruction of the fish and game found within said park, and against their capture or destruction for the purposes of merchandise or profit. He shall also cause all persons trespassing upon the same after the passage of this act to be removed therefrom, and generally shall be authorized to take all such measures as shall be necessary or proper to fully carry out the objects and purposes of this act.

Approved March 1, 1872.

In 1872 Mr. N. P. Langford was appointed superintendent of the Park, and in 1877 Mr. P. W. Norris was appointed as his successor. The latter has made several reports.

In 1877 the Nez Perces Indians raided the Park, killing a number ot people and destroying some property. Following them, General Howard entered the Park, building the road up the Madison and across to the Yellowstone River at Mud Volcanoes.

In 1878 the Bannack Indians crossed the Park on the trail leading from the Madison River to the East Fork of the Yellowstone and to Clarke's Fork. On the latter stream they were captured by General Miles, who was on his way to the Park with a pleasure party.

In the following chapters the numbers given the springs in the tables correspond with the numbers on the accompanying maps.

SECTION I.—SPRINGS ON YELLOWSTONE RIVER DRAINAGE.

CHAPTER I.

MAMMOTH OR WHITE MOUNTAIN HOT SPRINGS OF GARDINER'S RIVER.

About 3½ miles above the mouth of Gardiner's River, a branch of the Yellowstone, in the northwestern part of the Park, is one of the most remarkable developments of thermal action to be found in the world, remarkable principally on account of the extent of the deposits, as calcareous springs are probably the most widely distributed. (In Asia Minor there is a formation which from the description is the counterpart of our springs at Gardiner's River.) The deposits, which are largely calcareous, occupy an area of 3 square miles. Of this the recent

deposits, on which the springs are at present found, occupy about 170 acres. They extend over two miles back from the river, and the upper springs are 1,000 feet above its level. On the summit of a long, ridge-like mountain which extends south from the head of the gulch in which the springs are situated, is found also a thick deposit of old spring material, covering an area of about three-quarters of a square mile. Another area, including about 90 acres of old deposits, is found between the forks of Gardiner's River, southeast of the main springs. These remnants prove that formerly the springs at this locality must have extended over a much larger area than they do at present. These old deposits will be referred to again.

History.—These springs were not visited by the expeditions of 1869 and 1870, to the members of which they were unknown, because they followed the Yellowstone River, and, therefore, passed the mouth of Gardiner's River without seeing them. In 1871, when we first visited them, we found that several cabins had been erected, and that two men from Bozeman, Mont., had entered a claim to the springs, while a number of invalids were using the waters with benefit. They called the springs Mammoth Hot Springs. The first description ever published was that in the report of the survey for 1871.

Geology.—The geology of this region will be fully given in Mr. Holmes's report, and I will therefore only refer to it briefly. The rocks upon which the deposits are found are referable to the Middle and Lower Cretaceous and Jurassic formations. Rhyolite is found east of the springs, on the north side of the gulch, where it is in connection with the Jurassic. It is also found on the summit of the long, ridge-like hill, where it is capped with old hot spring deposits. Beneath the Jurassic rocks there are probably Carboniferous limestones, in which we have the source of the carbonic acid and carbonates that are found in the water of the springs. The comparatively low temperatures found here are also explained by the presence of sedimentary rocks, the water in passing through them losing a great portion of its original heat. South of the springs the local drift obscures the underlying rocks, but it is probable that they are mainly Jurassic and Cretaceous here as on the north side.

The springs at present are found mainly on two masses of deposit, and these are arranged in terraces. Of these there are four principal ones, which have minor subdivisions. The map shows the main divisions, which have a remarkable resemblance to each other. The lower mass, on which the most active springs are now situated, has at its foot two cones or isolated masses of deposit, and is fringed along its front with basins. The upper mass has a similar front, but its springs now are few and feeble in their action. Back of this upper mass is an older one still, at the foot of which are several old cones, which are shown in the left-hand lower corner of the map. This old upper mass is overgrown with trees, but the ruins of old basins can still be detected, almost covered with soil, and much broken down. Northeast of Lookout Hill another old terrace is found, with remnants of basins on its front. It is probable that at some time in the past springs were active on all the terraces, not perhaps simultaneously, but successively.

In the report for 1872 I divided the terraces into fourteen for the sake of comparison. As a map accompanies the present report, this will be unnecessary, and I will designate the springs by number, and in the description give their identification with the numbers and terraces of 1872, as far as can be done. The changes that have occurred since that time will be noted after I have given the descriptions of the different springs that are included in the following table:

THE PULPIT MAMMOTH HOT SPRINGS

STALACTITIC BASINS MAMMOTH HOT SPRINGS

MAMMOTH HOT SPRINGS.

Number and name.	Size.	Temperature.	Time of observation.	Temperature of air.	Remarks.
		°F.		°F.	
1		*a* 161 *b* 162 *c* 161½	3.15 p. m.	70	This spring, or springs rather, seem to take the place of the 2nd terrace springs of 1872.
2. Cleopatra Spring		*154	10.30 a. m	57	This is the most beautiful spring in the basin.
3. Little Joker	2 by 3 feet, 6 inches deep	143		68	This spring has a coating of carbonate of lime.
4	Spring not well defined	157	4 p. m	68	Water oozes from hill and spreads out into a pool.
5	Fissure 18 by 3 inches	89	8.30 a. m	53	Stream of water 5 inches wide, 1 inch deep, escapes. This spring is near the Bath Springs.
6. Bath Springs	18 inches by 2 feet	90			Water escapes from fissure into a basin.
7. Bath Springs	4 by 3 feet	100			Receives some water from No. 6.
8. Bath Springs		107			Small fissure.
9. Bath Springs		115			This is the main spring that supplies the bath houses.
10	3 by 5 feet, 1 foot deep	158			Back of the spring is a pool.
11	Pool 3 feet long	124			
12	4 to 6 inches diameter	152			Two bubbling holes.
13	4 to 6 inches diameter	152			
14	6 inches by 1 foot	157	10.15 a. m	57	
15	2 by 3 feet	157			
16	5 by 12 feet	143	1.15 p. m	61	Greenish basin in red-stained deposit.
17	15 by 20 feet	165			This is one of the principal springs, on what was known in 1872 as the 9th terrace.
18	12 by 20 feet	161			White basin with three centers of ebullition. It opens into No. 19.
19	Indefinite	164			White, with yellowish tinge and filaments radiating. There is a fissure in the center.
20	Small hole in a basin 6 feet wide and about a foot deep	165			Receives water from 18 and 19. Below it are flat, shallow basins.
21. Main Springs	Pool 100 by 200 feet	†147	2.30 p. m	65	There are in reality three pools; they are 10 feet lower than Nos. 18, 19, and 20.
22. Sulphur Spring	Irregular fissure	144			This spring is on a mound 12 feet above No. 21, and to the right of it.
23		165			This is where the small geyser-like springs once were.
24	2 inches diameter	162			The water spreads out over a wide space, and sinks in hole about 150 feet distant.
25	Small fissures	*a* 139 *b* 141 *c* 137	9.15 a. m	49	Slight escape of water, which spreads out on a flat and disappears.
26	Small holes in space measuring about 3 feet diameter.	*a* 157 *b* 153 *c* 155			There is considerable overflow; one hole bubbles spasmodically; *b* is temperatured at the lower end, *c* in the pool.
27	Mound-like mass with spring on top measuring 3 by 4 inches, and three points of bubbling, *a*, *b*, and *c*, at base.	160 *a* 161 *b* 158 *c* 161			This spring, with 25 and 26, are on lowest terrace in this secluded basin or depression.
28	Spring 4 by 10 feet on mound or terrace of 35 by 40 feet.	142			This spring is a remnant of what was not long ago an extensive terraced spring; white empty basins form the front. It is on a higher level than 25, 26, and 27.
29	Cannot define basin	164			There are three centers of ebullition.

*Both on the edge and in the center.
†On the edge.

MAMMOTH HOT SPRINGS—*Continued.*

Number and name.	Size.	Temperature.	Time of observation.	Temperature of air.	Remarks.
		°F.			
30	Small mound with 2 openings.	*a* 121 *b* 120			In a rather isolated depression.
31	Three small cones about an inch each in height.	*a* 125 *b* 112 *c* 120			These are on the same ridge of deposit with 34, 35, 36, and 37, only further north, where it is much lower and overgrown with pines.
32	150 feet long	91			Lake like pond.
33	20 feet diameter	89			Round spring near 30 and 31.
34 35 36 37 38	These are on a long mound of deposit, perhaps 200 feet long, 10 feet high.	151 150 141 153 156			
39	Small holes	*a* 143 *b* 144 *c* 144	10.30 a. m	63	These are small holes on a ridge or mound of deposit similar to that of 34–38.
40		105			One of several oozes further down the ridge of 39.
41		128			Spring on low mound. Beyond are several old cones.
42	*a* 4 feet diameter	*a* 105 *b* 112 *c* 102			*b* and *c* are oozes nearer the road than *a*.
43	Small oozing holes	*a* 103 *b* 110			Between 42 and the road.
44		125			Nearest to road.
45	*a* 2 by 2 feet *b* cone 6 inches high *c* cone 4 inches high *d* 8 inches high	135 142 138 107			Low mound next to the Glen Grotto.
46		*a* 130 *b* 136			At the north base of the Glen Grotto; between *a* and *b* is a dead cone.
47. Glen Grotto	Oblong mound with cones of 6 inches to a foot height on top.	*a* 148 *b* 148 *c* 130 *d* 106 *e* 147			*a* and *b* are at the north end; *a* is coated with sulphur; *b* is a bulger, and with *a* spurts a few inches; *c*, *d*, and *e* bubble slightly, and are at the south end of the mound. Between the two groups are dead cones.
48		83			Conical mound in broad basin.
48 *a*. Cave Spring		90			
48 *b*. Small springs in grass.		63 91			
49	2 holes each about 3 feet diameter.	*a* 141 *b* 141	2.40 p. m.	65	
50		117	3.15 p. m.		On the river's edge; there are others near these. These three are close together.
51		84			
52		115			

DESCRIPTION OF THE SPRINGS.

No. 1.—There are here two basins with two springs each (*a* and *b*, *c* and *d*). They are opposite the cabin on the lower level, and have hard, white basins. The greatest amount of water gushes out at *c* and spreads out over a sulphur-lined, shallow basin; in this are filament-like threads of sulphur-covered deposit. Below, the water has formed shallow pools, some of which have a red lining. Back of the springs are old basins reaching as far as the Bee Hive cone. These springs occupy the place where, in 1871 and 1872, we saw the delicate, pink-tinged shallow basins. The temperatures (161°, 161½°, and 162° F.) are the same as those of the second terrace of 1872 (springs 56 and 57 of table, page 123, Report

LOWER BASINS MAMMOTH HOT SPRINGS

GENERAL VIEW OF MAIN TERRACE MAMMOTH HOT SPRINGS

for 1872). They have moved down about 100 feet. In 1871 they were near the Bee-Hive, having broken out in August of the preceding year. They broke out in their present situation in the fall of 1875, and in 1873 were about half way between the two locations. These notes were furnished me by Mr. McCarthy, who has had a permanent residence at the springs. The basins are from 6 inches to a foot and 2 feet high, and are irregular in shape; they are from 6 feet to 15 or 20 feet in length. The lower deposit is soft, and the water when it reaches this point has a temperature of only 88° F. Sulphureted hydrogen is given off. On the terrace back of these springs, around the Liberty Cap, are shallow basins, mostly empty and broken down, the deposit being soft.

No. 2. *Cleopatra Spring.*—This spring was named by some of the earlier visitors to the springs, and is one of the handsomest in the group. It is on the summit of a mass of deposit that is 40 feet in height and covers an area of nearly three-fourths of an acre. On the summit is the spring, which has light-blue-tinted water in a white basin, with light yellowish-red edges. A large flat basin surrounds the spring. At the east end are basins lined with reddish tufted material. The greatest overflow escapes at the west end, and the basins here are fringed with stalactitic masses, as shown in Plate I. The basin at the edge here where these stalactites are most prominent is 8 feet high. Below it the water flows over an incline, at the base of which are handsome white, red, and yellow basins. The whole front of the mass is lined with these basins, and on the west side, where the overflow was in 1871, they are snowy white. The amount of water is very small in comparison with the amount of deposit. It sinks out of sight at the base of the mass. This spring has a temperature of 154° at the edge. As the water escapes it flows over a ladder that has been placed against the edge for the purpose of coating articles that are hung on it. The rate of deposition under favorable circumstances is about one-sixteenth of an inch in 4 days (96 hours). The illustration will give the best idea of this mass and the basins that compose it. It is almost impossible to describe them in words. The spring is 20 below the terrace, immediately back of it, and 90 feet below the terrace of springs 11–15. The terrace immediately back of it appears to be composed of laminated deposit. Below the Cleopatra mass is an irregular terrace of old basins which is 25 feet high, and below this is the terrace on which Spring 10 is located. This terrace is about 78 feet above the level at the base of the Liberty Cap. Spring No. 3 is nearly at this level. The front of the main terrace facing this lower level has old gray and white basins which are in ruins.

Liberty Cap.—This curious mound or chimney is well shown in Plate I*a*. It is about 45 feet in height, and is composed of overlapping layers of sediment, having evidently been built up by the overflow of the water from the orifice at the top, the evaporation of the water depositing the sediment in layers, until either the mass became too high for the hydrostatic pressure, or the water, having found a new outlet, left the channel in this cone. It is about 20 feet in diameter at the base. The deposit is hard, of close, compact structure, and evidently of considerable age. Surrounding this cone are a number of shallow basins, some of which are snowy white, tinted with pink. But few active springs are found here at present. It is probable that certain springs, especially No. 1, have shifted their position, building up these basins one after another or in groups. The older deposits are gray, and much broken down. Near the back of this terrace, in the side of the mass rising from it, is a second cone, not so high. It is called, on the map, Liberty No. 2, and has sometimes been called the Bee Hive. Below the shallow basins which

form this subterrace is a wide flat, which probably once was a spring terrace, in which the traces of the basins have been completely obliterated. This flat gives the best view of the main terraces. The mass which they form is nearly 300 feet above it, and its white and gray colors contrast with the green of the fringing pines like a huge frozen cascade suddenly arrested in its descent. No living trees are found where there are any new deposits, although many dead trunks are scattered over them. On the old gray deposits, however, pines have grown since the disappearance of the springs. Almost east of the Liberty Cap is the spring next to be described, viz, the "Little Joker."

No. 3. *Little Joker.*—This is a small hole 2 feet by 3 feet, and only 6 inches deep. Its surface is covered with a crust of lime carbonate. In the outlet is a sulphur deposit in fine, silky, thread-like filaments. The temperature of the water is 143° F. It stopped flowing in 1874, and began again in 1876. It was once used for bathing, and has been used for drinking purposes when cooled. It is said to have been beneficial in rheumatism. It has a cathartic action, as most of the other springs at this place have in a less degree.

No. 4.—Twenty feet below No. 3 are several holes out of which the water oozes from beneath the deposit, and spreads out into a large shallow pool that is surrounded with red gelatinous material. It is impossible to define the basin, but the average temperature where the water gushes is 157° F.

Nos. 6 to 9. *Bath Springs.*—These springs are so called because the water from them is led by wooden troughs into the bath-houses. Most of the water is supplied by No. 9, which is a small fissure-like hole. Although the springs are small, the flow of water is vigorous. The channels and wooden troughs are covered with a bright-green confervoid growth, mingled with which is a brown growth. These springs are 10 to 20 feet in elevation above the Little Joker. The temperatures are 90°, 100°, 107°, 115° F. In 1871 the temperature was given as 92°.

No. 10, as we have already noted, is situated on the main terrace below the Cleopatra Spring. It is 3 feet by 5 feet, and 1 foot deep. It has a hard, irregular, cell-like basin. In the outlet are sulphur filaments. The water after flowing down an incline fills large basins. The deposit is white, brownish-red, and yellow. The temperature of the water is 158° F., and sulphureted hydrogen and carbonic acid gas escape in bubbles from its surface. Back of the spring is a large pool covered with a crust of lime carbonate. This deposit is also noticed on the surface of the water in some of the basins below the spring. The temperature here in 1871 was 155° F. In 1872 the temperature was noted as 152° F. The spring is in a sort of a ravine, and southwest of it is an irregular terrace, over which the road to the Gibbon Geyser Basin ascends the mass of deposit.

Nos. 11 to 15 form a small group on a flat-topped mound which is really a spur or projection from the main terrace (ninth terrace of the description in the report for 1872). The level of this mound is 90 feet above the Cleopatra Spring, and about 190 feet above the Bath Springs. The sides of the mound are arranged in beautiful reddish and reddish-gray basins, from 2 feet to 18 feet in size, very irregular, and from 6 inches to a foot or more in depth. Plates III and IV show some of the basins near the base of the mound. The springs are small and comparatively unimportant. They are sufficiently described in the table. The highest temperature was 157° F. In 1871 the highest taken here was 158° F., and in 1872, 157° F., so that the temperature is probably unchanged. Between the projection on which these springs are situated and the one on which the main springs (21) are located there is a depression in which are basins arranged like

SUMMIT OF MAIN TERRACE IN 1871. MAMMOTH HOT SPRINGS

SUMMIT OF MAIN TERRACE IN 1878. LOOKING SOUTH. [illegible] HOT SPRINGS.

a stair-case leading from the terrace. They are arranged in a comparatively narrow line near the lower end, and look somewhat like a line of tubs piled one above the other. They extend down about 100 feet. Below them the deposit is much broken, and consists of a mass of soft, crumbling, white calcareous material. There are remnants of old basins, among which dead trees are standing. Old basin ruins are seen also toward the summit of the terrace. The deposits are white mingled with red and yellow. On the east side of the mound on which are the springs just described the basins are well marked, and extend down about 15 feet below the level of the springs. Fifty-five feet below is a projection or table on which Spring No. 16 is located.

No. 16 is a greenish basin 5 feet by 12 feet, surrounded by red-stained deposit. Where the water overflows, green filaments like a confervoid growth are seen in the channel. The temperature of the water in this spring is 143° F.

Ninth terrace of 1872.—This, at present, is really the main terrace level, and is well shown in Plate V. It includes ten acres, and is about 280 feet above the level of the springs opposite the Cabin (Spring No. 1), and about 200 feet above the camping place near Lookout Hill. On the east and north sides the basins are prominent. The subterrace on which Nos. 11 to 15 are is really a part of this terrace. On the northwest or north side is a long ridge 3 to 5 feet high, which in 1871 had a fissure in which the boiling water could be heard; and at its south or west end was a spring with a temperature of about 162° F. This spring has disappeared, although the fissure remains, and boiling can be heard far beneath. On the south or southwest side of the terrace is another ridge-like mass of deposit, 30 feet high, which is separated from the terrace level above by a hollow. Near the base of this ridge, a little above the level of the terrace, is a mass of stalactic deposit, once the site of a spring, which, from the curious shape, has been termed the Pulpit (Plate III). In 1871 the fissure extending along this ridge was filled with boiling water and steam, and sulphuretted hydrogen escaped from it, as it did also in 1872. From Professor Comstock's account (page 208 of Jones's report) it was active in 1873, but this year (1878) it is almost extinct; only at the northern end, in the hollow between the ridge of next terrace, is there any sign of life, where there is a slight escape of water from a small fissure (Spring No. 23). The temperature in this spring is 165° F. This is really the site of the small geyser tubes that in 1871 spouted intermittently to the height of 3 feet. In 1873 there were three boiling springs here, but the geysers were not in action. Now, however, we find only one spring, and a cone in which the spring is extinct. The gully leading from this cone opens out onto the main terrace. Returning to this we find two main groups of springs (17 to 20 and 21) on the central portion of the terrace, and another slightly raised above its level.

No. 17.—This is the principal spring of the first group. It measures 15 feet by 20 feet, and has a beautiful white, marble-like basin, in which the transparent water has an exquisite light-blue tint. At a number of places on the surface are scum-like masses of lime carbonate floating about like cakes of ice; some of them are red on the surface. The water boils and bubbles constantly, a large portion of the ebullition being probably due to the escape of carbonic acid gas and sulphuretted hydrogen gas. The temperature is 165° F. The water from the spring spreads out in minute terraces and shallow basins, extending toward the group 11–15, and toward No. 21 particularly. Beneath the crust

back of this spring there is a deposit of sulphur in the main mass of the sediments.

No. 18 is a pure white basin 12 feet by 20 feet in its dimensions, with three centers of ebullition. The water has a temperature of 161° F., and a portion of it flows out into No. 19.

No. 19 is a yellowish-white flat basin, with a fissure in the center and several holes in which the water bubbles and boils. The size of the spring is indefinite, as it opens out into No. 20. In that direction are yellow sulphur-tinged filaments which radiate from the margin of the spring. The temperature was 164° F.

No. 20 is a hole in a basin that measures about 6 feet in width and a foot in depth. It receives water from the springs above (19 and 20), but in the active portion of the spring has a temperature of 165° F. Below it are the radiating sulphury filaments that are seen between it and No. 19. They spread out on flat, shallow basins, which are white and red in color, and are very handsome in some places. These are best appreciated by a reference to the accompanying plates (Plates V*b* and V*c*), which show the general appearance of the terrace in 1878. This group in 1871 was much nearer the base of the ridge, and the water spread over the greater part of the terrace so that it was only on the edges that we could walk. We can now go over the very place where the spring then was without any danger. There was a great change from 1871 to 1872, and even more to 1878, as a comparison of Plates V*a*, V*b*, and V*c* will show. The highest temperature in this group in 1871 was only 162° F., because we could get only the temperature at the edge of the spring and not in the center of ebullition. Near the springs are several fissures and cavities, the chambers of extinct springs, in which are fragile stalactitic masses of deposit of pure white and light yellowish colors. They have been formed by the percolation of water through the mass of sediment. At the foot of the ridge back of these springs is a mass pulpit-shaped, from which we called it the Pulpit. It marks the site of a former spring. The changes from 1871 to 1878 in the springs of this portion of the terrace are best shown by the photographs taken in the two years (Plates V*a*, V*b*, and V*c*), although they were taken from slightly different points in order to best show the springs. Plates V*a* and V*c* are from nearly the same point of view, the latter being taken from a point a little more to the right.

No. 21. *Main spring.*—This spring occupies very nearly the same position it did in 1871 and 1872. It may, perhaps, reach back a little farther from the edge, but the change in position, if any, has been slight. It is a large pool-like spring about 100 by 200 feet. It reaches back to the white basins that spread out below the group just described. It is 10 feet lower than they are, and the basins between are empty. Surrounding the spring are large shallow basins and pools, some of which are lined with a red deposit. East of the spring, on the slopes leading down from the edge of the terrace, are some of the handsomest basins to be found at the locality (Plate VI). The tubs are irregular in size and shape, and extend far down the sides. The edges of many are tinged of a rusty color. The temperature of the water could be obtained only at the edge, where it was 147° F. In 1871 a temperature of 155° F. was recorded for this spring; 162° was recorded in 1872. These temperatures were probably all at different points. The line of tubs extending down the ravine between the main spring and group of 11–15 has been mentioned when speaking of the latter.

No. 22 is a sulphur spring on a mound of deposit at the south end of the ninth terrace, above the general level of which it is raised 12 feet. It

SUMMIT OF MAIN TERRACE IN 1878 LOOKING NORTH MAMMOTH HOT SPRINGS.

FISSURE RIDGE BACK OF MAIN TERRACE MAMMOTH HOT SPRINGS

is irregular in shape, and the water comes out from a fissure and has a temperature of 144° F. In 1871 it was 150° F., which appears to indicate a diminution in its activity. The ridge back of the ninth terrace (Plate V*d*) is the tenth terrace of the table in the report for 1872. It has been described, and I pass on to the next terrace level.

Eleventh terrace of 1872.—This terrace is 40 feet above the ninth terrace, and has an area of over 13 acres, over which grass grows to a great extent. The principal spring (24) is near the edge of the terrace that overlooks the gully between the terrace, and the ridge just back of the ninth terrace.

No. 24.—This spring is a couple of inches in diameter, and the water as it comes from the deposit spreads out to the right and left over a white surface coated with yellow sulphury filaments that appear soft and silky. The water that goes to the right disappears in a sink-hole about 150 feet distant. The temperature is 162° F., which is higher than that observed in 1871 (156½°). The terrace level extends southward to the high bluff of the thirteenth terrace. On the west is another ridge, on the summit of which is a fissure and a cone which once were active springs. The water still bubbles slightly in them, but they do not deserve the name of springs. Where the road crosses the end of this ridge next to the hill the water oozes from the deposit. Extinct basins are found on the sides of the ridge. Between this ridge and the bluff of the thirteenth terrace is a mound with dry basins on its sides. Toward the ridge just described a spur of old deposit extends from the thirteenth terrace, in which the laminated overlapping structure of the mounds is well shown in the places where it has weathered and has been broken down. Some of the mounds are overgrown with pine trees which give evidence of the age of these deposits. This, however, is more particularly noticed on the thirteenth and fourteenth terraces, and will be referred to again. The best view of the springs of the ninth terrace is to be had from the edge of the eleventh terrace, which directly overlooks them. Dr. Hayden, in the report for 1871, describes it as follows:

> The wonderful transparency of the water surpasses anything of the kind I have ever seen in any other portion of the world. The sky, with the smallest cloud that flits across it, is reflected in its clear depths, and the ultramarine colors, more vivid than the sea, are greatly heightened by the constant, gentle vibrations. One can look down into the clear depths and see with perfect distinctness the minutest ornament on the inner sides of the basins; and the exquisite beauty of the coloring and the variety of forms baffle any attempt to portray them, either with pen or pencil. And then, too, around the borders of these springs, especially those of rather low temperature, and on the sides and bottoms of the numerous little channels of the streams that flow from these springs, there is a striking variety of the most vivid colors. I can only compare them to our most brilliant aniline dyes—various shades of red, from the brightest scarlet to a bright rose tint; also yellow, from deep-bright sulphur, through all the shades, to light cream color. There are also various shades of green, from the peculiar vegetation. These springs are also filled with minute vegetable forms, which under the microscope prove to be diatoms, among which Dr. Billings discovers *Palmella* and *Oscillara*. There are also in the little streams that flow from the boiling springs great quantities of a fibrous silky substance, apparently vegetable, which vibrates at the slightest movement of the water, and has the appearance of the finest quality of cashmere wool. When the waters are still these silken masses become incrusted with lime, the delicate vegetable threads disappear, and a fibrous spongy mass remains, like delicate snow-white coral.

At present the colors are white and red, with which the blue color of the spring contrasts beautifully. At the south end of the eleventh terrace is a long, narrow, spur-like ridge from the thirteenth, covered with a growth of pines. Crossing this we come to a somewhat inclosed area, which is the twelfth terrace of 1872.

Twelfth terrace.—This was the seat of very active springs in 1872, which were not there in 1871. They are now dying out again. The springs are at two different levels. A slight terrace between them has at present no springs, although the snowy-white basins show that it is not long since they disappeared.

Nos. 25, 26, and 27 are on the lower level.

No. 26 marks the location of several small holes that bubble in a space of about 3 feet diameter, surrounded with a reddish deposit on which there are the soft silky filaments. There is considerable overflow, and one of the holes bubbles spasmodically, giving off sulphureted hydrogen gas. The water spreads out in a pool.

No. 25 marks the place of three small fissures. The flow of water is very small, and it soon spreads out on the flat surface of the deposit and disappears.

No. 27 is a raised mound, and on the summit is the spring with a temperature of 160° F. There are three bubbling points at the base of the mound.

No. 28 is on the upper level, on the summit of a mound measuring 35 feet by 40, with white basins on its front. It is a white spring, and has a coating of lime carbonate on the surface. The water has a temperature of 142° F. Back of these springs is the bluff of the thirteenth terrace.

At the foot of the narrow ridge which separates the eleventh from the twelfth terrace are two oblong mounds that in 1872 had some of the most active springs of the twelfth terrace. They appear to have ceased flowing recently, judging from the appearance of the deposit. By referring to the table of springs it will be seen that of the eight temperatures taken only one was at all high, and it was only 160° F. Of the eight temperatures taken in 1872 three were 162° F., and five 160° F.

Thirteenth and fourteenth terraces.—For the purpose of description these two terraces may be considered as one, with a very irregular surface. As seen from the surrounding hills it presents a quite uniform surface back for some distance, and its edges, fronting the wagon road and the eleventh terrace, are fringed with old empty basins. It must once have been a prominent part of the springs, far exceeding the present state of the ninth terrace, to which it bears some resemblance. When it was the seat of active springs the eleventh terrace held the same relation to it that the area about the Liberty Cap does to the ninth terrace, the mounds and ridges on the eleventh terrace corresponding to the Liberty Cap and Bee Hive. The mounds and ridges on the back part of the nineteenth terrace hold the same relation to the old terrace, the bluff face of which now forms the upper limit of the active springs. This old terrace is concealed by the very heavy growth of timber which covers its sides, but traces of old basins can still be seen along the wagon-road which goes up over it. Back of the level portion of the thirteenth terrace the surface is broken into hollows and ridges, all heavily timbered. Beyond these is what was described as the fourteenth terrace in 1872. At some places, particularly near Glen Grotte, its level is slightly below that of the thirteenth terrace. On the west side of the latter a ridge with a fissure, like the one on the ninth terrace, rises above the road. This must once have been the site of active springs. The slopes facing the wagon-road are covered with old gray basins. At the summit a little steam still escapes. On the east side of the terrace, at the edge of the bluff overlooking the twelfth terrace, there have been active springs recently. There are fissures in the deposit, from which there is a slight escape of steam.

EASTERN BASINS. MAMMOTH HOT SPRINGS

In the timber growing on these terraces we have the evidence of the great age of the springs. It is impossible, of course, to even estimate the number of years. We do not know the thickness of the sediment, and after the springs which deposited it ceased their action it may have been a long time before the conditions were favorable for the growth of the pines which we now see growing there, and yet some of them have a diameter of nearly three feet, which would be equivalent to a growth of more than five hundred years. In some places, after the trees gained a foothold, new springs broke out, and killed them. It is probably true, as Dr. Hayden said in 1871, "that all the deposits in the immediate vicinity of the active springs are constantly changing from the margin of the river to the top of the White Mountain and return." The deposits in these upper terraces are of great extent, but the water flowing from them now is comparatively small in quantity, and the temperatures with but one exception are low.

No. 29.—This spring is on the edge of the thirteenth terrace, just above the point from which starts the ridge that separates the eleventh from the twelfth terrace. It is at a considerably higher level, and between the springs and the beginning of the ridge is a succession of basins built by the water which comes from above. The water spreads and runs into a sink-hole. The basin of the spring cannot be defined; there are three holes from which the water, which has a temperature of 164° F., escapes.

No. 30 is a small mound in a somewhat isolated basin, which will be found best by reference to the map. It has two openings from which water flows. The temperatures are 120° F. and 121° F.

No. 31.—This is the northern end of the ridge or mound on which Nos. 34–38 are situated. There are three small conical chimneys, each about an inch in height, from which there is a slight flow of water, with temperatures of 112° F., 120° F., and 125° F. This portion of the mound is covered with a growth of pines, which obscures the situation of the springs.

No. 32.—This is a pool 150 feet in length at the foot of a gully, with a mound of deposit on both sides. The water is generally clear and has several points of ebullition. The temperature is 91° F. Back of this spring there are mounds and ridges, after crossing which we come out into the open space in which Glen Grotto and other mounds are situated. They will be described farther on.

No. 33 is a round spring, about 20 feet in diameter, with a temperature of 89° F.

Nos. 34–38 are small cones on the top of a long ridge-like mound of deposit that is 10 feet in height and has a length of about 200 feet. A number of the cones are extinct as regards the springs. The temperatures given in the table range from 141° F. to 156° F. Following the mound southward we find an old fissure, overgrown with cedars, and a short distance beyond this the fissure contains a little warm water. Still farther north are the springs described under No. 32. This ridge forms the eastern boundary of a level which reaches westward to the wagon-road. Back of this, which is the fourteenth terrace of the description in my report for 1872, is a high bluff of deposit, covered with a thick growth of pines. This immense mass of deposit extends to the head of the gully. It is covered generally with soil, which obscures the old basins. Traces of the ruins can still be seen at places. At the foot of the bluff which marks the northern end of this mass are several cones or mounds and a ridge similar to the one just described.

No. 39 marks the position of the ridge just mentioned. It extends

from the bluff like a spur. Near the beginning of the mound are several small holes, from which there is a slight escape of water that trickles down the side of the mound. The temperatures are 143° F., 144° F., and 144° F. At the head the mound is about 25 feet high. It extends towards the oblong mound (Glen Grotto) and diminishes gradually in height until it ceases, and the line is continued by several broken mounds and cones.

No. 40 marks the site of several springs farther down the mound; the temperature is 105° F. At this point, on the west side of the mound, there is a marshy area with several pools of water.

No. 41 is a spring on a low mound, with a temperature of 128° F. Here the ridge runs out into the marsh, and beyond are several old cones, remnants of the ridge. West of these cones and dead mounds are marshy spots with oozing springs. Below them are the following springs:

No. 42.—This is a spring 4 feet in diameter, from which bubbles of carbonic acid gas escape. The temperature is 105° F. Above it are several holes from which water oozes, near the road. Here the temperatures are 102° F. and 112° F.

No. 43.—Two oozing holes between No. 42 and the road; the temperatures are 103° F. and 110° F.

No 44 is nearest to the road, and has a temperature of 125° F.

These springs just described are all somewhat concealed in the grass, and all give off carbonic acid gas.

No. 45 is a low, flat, oblong mound, in which the present openings mark what was probably once a fissure extending along its entire length. At present the fissure is closed, and in the small cones we have shown, on a small scale, the process by which the larger mound was built, viz, by the overflowing water depositing layer upon layer. There are three cones and one flat-rimmed spring. The temperatures range from 107° F. to 135° F.

No. 46.—At the north end of the Glen Grotto, between it and the mound of No. 46, are two small cones, one of which has an active spring and the other dead. There is also a small spring. The temperatures are 130° F. and 136° F.

The slope of the mound above these springs is constantly wet by the water that flows from the springs on the summit.

No. 47.—*Glen Grotto* (Plate VI, *a*.) This oblong mound is about 50 feet in length by 25 or 30 feet wide, and is about 20 feet above the general surrounding level. The wagon-road passes near one end of it, so that it is readily found. On the summit there are seven or eight cones, five of which have active springs. Besides these there are a number of old holes that once were occupied by springs. *a*. Throws the water out with a spurt which reaches 5 or 6 inches in height. It has a temperature of 148° F., and is surrounded with a coating of sulphur. *b*. Also bulges, and has a temperature of 148° F. *c*. *d*. and *e*. Have temperatures, respectively, of 130° F., 106° F., and 147° F., and are bubbling springs.

The cones which these springs have formed are from 6 to 8 inches in height, and show the same method of formation that the large mound does, viz, the overlapping layers. The sides of the mound are colored of a rusty yellow in places, and dead trees stick through the deposit, having been killed by the hot water and the accumulation of the Calcareous sediments. The springs present about the same appearances noted in 1871 and 1872. In the former year the temperatures ranged from 142°

GLEN GROTTO MAMMOTH HOT SPRINGS

F. to 143° F., and in 1872 they were 130° F. to 148° F., indicating that there has been little if any change in this respect.

No. 48.—Above the mounds on a flat area there are several old spring holes, only one of which contains water at the present time. The others have probably been extinct for a long time. The water in the conical mound, which is at present the only spring here, has a temperature of only 83° F. Above this flat we find several small springs.

No. 48 *a*.—This is at the foot of a cave-like opening in the deposit, and is a mossy-lined hole with several points of ebullition or bubbling. The temperature is 90° F. Above it are several holes, the sites of old springs.

No. 48 *b* marks the location of several small and unimportant springs that are almost concealed by the grass at the foot of the ridge that ends the rough part of the thirteenth terrace. The temperatures are 63° F. and 91° F. There are at present no active springs above the fourteenth terrace.

At a number of places in the old sediments caves are found, the roofs of which are ornamented with stalactites, and in which bones of animals are found. One is described by Professor Comstock in his report,* which he considers to be the basin of an extinct spring. The opening was hopper-shaped, 6 feet long by 3 feet in width, and beneath was a chamber 9 feet in height, with a steep, sloping floor covered with a thick deposit of vegetable mold. On one side of the sloping floor, near the bottom, the skull and bones of a bison. These caves are the resort of wild animals, and the bison bones were either carried in by them, or, as Professor Comstock thinks, the animal fell through some larger opening and passed into the chamber or cave trying to find a passage out. The bones were imbedded in the soil, from which he draws the conclusion that the animal perished a long time ago, but at a much later period than the date of the extinction of the spring. I have already referred to the old compact deposit found on the long mountain ridge south of the springs. This was visited by Dr. Hayden in 1871, who thus describes it (Report for 1871, page 71):

> Upon the margins of the mountain, high above the present position of the hot springs, is a bed of very white or yellowish-white limestone, 50 to 150 feet thick, and appearing in the distance like very pure Carboniferous limestone. It is regularly stratified, and the jointing is complete, and immense masses have fallen down on the slope of the mountain side. There is a belt a mile long and one-fourth of a mile wide, covered with immense cubical blocks of the limestone 50 to 100 feet in each dimension, usually with the wedge-shaped end projecting upward, as if the mass had slowly fallen down as the underlying rocks were worn away by erosion. So thickly is this belt covered with these huge masses that it is with the greatest difficulty one can walk across it. It would seem that this bed must at one time have extended over a portion or all of the valley of Gardiner's River. Much of the rock is very compact and would make beautiful building-stone, on account of its close texture and color, and it could be converted into the whitest of lime. If the rocks are examined, however, over a considerable area, they would be found to possess all the varieties of structure of a hot-spring deposit. Some portions are quite spongy, and decompose readily; others are made up of very thin laminæ, regular or wavy, enough to show the origin of the deposit without a doubt. But in what manner was it formed? I believe that the limestone was precipitated in the bottom of a lake, which was filled with hot springs, much as the calcareous matter is laid down in the bottom of the ocean at the present time. Indeed, portions of the rock do not differ materially from the recent limestones now forming in the vicinity of the West India Islands. The deposit was evidently laid down on a nearly level surface with a moderately uniform thickness, and the strata are horizontal.

The Gardiner's River Springs have frequently been compared to the Te Tarata Springs of New Zealand, where the basins have the same

* Reconnaissance of Northwest Wyoming, pp. 212, 213.

general form, but instead of being composed of calcareous material are siliceous. The Te Tarata (described in Part III of this report) covers an area of about 12 acres, and the head of the deposit is nearly 80 feet in elevation above the level of the lake. The springs and formations near Hierapolis, however, more nearly resemble our springs. (See description in Part III.) But even they are not so extensive. The formation, however, is calcareous, very like that of the Mammoth Hot Springs.

In various parts of the region west of the Rocky Mountains also are old deposits from hot springs which, when active, must have closely resembled the Gardiner's River Springs.

CHAPTER II.

SPRINGS OF THE YELLOWSTONE RIVER BELOW THE GRAND FALLS, INCLUDING THE EAST FORK.

In this chapter will be described three spring areas somewhat separated from each other.

The first area includes the springs of Junction Valley and Tower Creek, which are situated in rhyolitic rocks.

The second area includes the almost extinct springs which are located in Tertiary rocks.

The third area is that just south and southeast of Mount Washburn, and includes the Washburn Groups, the springs of the Grand Cañon, the Orange Creek Springs, and the Wayside Group. The two latter are not indicated on the geological map of the Park. The Forest Group might also have been described here, but it is just on the edge of lake deposits of Hayden's Valley, and I have therefore put it in the following chapter (III).

JUNCTION VALLEY SPRINGS.

In Junction Valley, the beautiful small valley in which the East Fork joins the Yellowstone, there are several unimportant springs which were not visited this year, as it was nightfall when we passed them, and we did not deem them of sufficient importance to delay, especially as they were examined in 1871 and 1872. The positions of the springs are indicated on the geological map (Mr. Holmes's). The first spring noticed is on the west side of the trail. It is small, and barely warm, giving a deposit of sulphur.

In the lower end of the cañon of the Yellowstone that begins at Tower Creek and extends to Baronette's Bridge there are numerous small sulphur springs. They are near the edge of the river in an inaccessible place, and give off sulphuretted hydrogen in such quantity that it is easily recognized on the upper edge of the cañon 500 feet above the springs.

Most of the springs in this region, however, represent the last stages of thermal activity, and are only referred to here for the sake of completeness. Sulphur appears to be the most abundant deposit; iron-stains were also noted on the sides of the cañon.

TOWER CREEK SPRINGS.

On the west side of the Yellowstone, between the mouth of Tower Creek and Antelope Creek (formerly called Warm Spring Creek), there

DEPARTMENT of THE INTERIOR
U S GEOLOGICAL SURVEY OF THE TERRITORIES
F V HAYDEN U S GEOLOGIST IN CHARGE

MAP OF THE WHITE MOUNTAIN OR MAMMOTH HOT SPRINGS

ON GARDINERS RIVER

YELLOWSTONE NATIONAL PARK

Plotted by

HENRY GANNETT, M E

From notes and sketches by

J E MUSHBACH

1878

Scale of Feet

JULIUS BIEN & CO. LITH

is a collection of vents and small warm springs or oozes. Only one is well defined. It is about 2 feet in diameter and 18 inches in depth, having a black muddy basin. The water, which is acid in its reaction, has a temperature of 127° F., and gives off sulphuretted hydrogen and carburetted hydrogen. Sulphur and alum are the principal deposits. The atmosphere is so impregnated with the gases that the springs are readily found. One has simply to be guided by his nose. There is a black deposit, which is probably partly carbonaceous, surrounding the springs. On the east side of the Yellowstone, opposite the mouth of Tower Creek, the high bluff is brilliantly colored with sulphur which has been deposited from hot springs. On the edge of the river the old deposits are abundant, consisting mainly of sulphur, selenite, and alum. There are no active springs; the ruins mark only the seat of former activity. The only active springs here now are on the west side of the river.

SPRINGS ON EAST FORK OF YELLOWSTONE.

On the East Fork of the Yellowstone, a few miles abovethe mouth of Soda Butte Creek, there are two small spring areas in which most of the springs are dead or dying, and do not therefore deserve special mention beyond this reference. Mr. P. W. Norris, in his report for 1880 (page 7), mentions the discovery, on one of the forks at the head of the East Fork, of a spring area resembling that of Soda Butte. It lies just outside of the limits of the Park. On Soda Butte Creek, 2½ miles above its mouth, stands the cone or butte from which the creek is named. Although named *Soda* Butte, it is composed mainly of calcareous material in which there is probably only a trace of soda, if it exists at all. It is a conical mound about 20 feet high, 25 feet in diameter at its base. It is situated on a sort of platform, of the same deposit, which is 75 feet long and is 15 feet above the surrounding level. It contains no water, nor is there any hot spring near it at present. A cold spring close by gives an acid reaction, tastes strongly of alum, and gives off sulphuretted hydrogen. The cone was doubtless once a geyser or spouting spring, and is interesting from the fact that it is now a ruin and teaches something of the formation of springs. Dr. Hayden, writing of this cone, says:

> This old ruin is a fine example of the tendency of the cone to close up its summit in its dying stages. The top of the cone is somewhat broken, but it is 18 feet in diameter at this time, and near the center there is a hole or chimney 2 inches in diameter, plainly a steam vent. This marks the closing history of this spring. The inner portions of this small chimney are lined with white enamel, thickly coated with sulphur, which gives it a sulphur-yellow hue. The base upon which the cone rests varies in thickness. On the east side huge masses have been broken off, exposing a vertical wall 20 feet high, built up of thin horizontal laminæ of limestone. On the west side the wall is not quite as high, perhaps 8 or 10 feet. It would seem, therefore, that it was at first an overflowing spring, depositing thin horizontal layers until it built up a broad base 10 to 20 feet in height; then it gradually became a spouting spring, building up with overlapping layers like the thatch on a house, until it closed itself at the top and ceased.*

The tufa which composes the mass of the deposit is similar to that of the Mammoth Hot Springs of Gardiner's River. We have not far to look to find the source of the lime. In the geological map Mr. Holmes colors a strip of Carboniferous limestones on the north side of the valley a short distance below the Butte. On the Carboniferous rest late volcanic Tertiary rocks. As Dr. Hayden says, there is no doubt that the limestones pass underneath the valley of the East Fork, and from the passage of the water through these the lime which predominates was

*Report U. S. Geol. Survey for 1871, 1872, p. 138.

obtained. The spring alongside is lead-colored and has a deposit of alum around it. It is on the bank of a small creek or rivulet and has a most disagreeable taste. This spring has long been noted among prospectors and Indians for its medicinal properties. Speaking of its taste, Dr. S. Weir Mitchell says:*

I do not distinctly recall all the nasty tastes which have afflicted my palate, but I am quite sure this was one of the vilest. It was a combination of acid, sulphur, and saline, like a diabolic julep of lucifer matches, bad eggs, vinegar, and magnesia. I presume its horrible taste has secured it a reputation for being good when it is down.

MOUNT WASHBURN GROUPS.

The area bordering the Grand Cañon of the Yellowstone, on the west side, extending back to the foot of Mount Washburn and the base of Dunraven Peak, is a heavily-timbered region. This interferes with the determination of the exact localities of the groups of springs which are situated here. In 1872, after almost passing around Mount Washburn, we crossed a high saddle some distance east of the main trail, and camped in the timber near the eastern base of the spur extending south from Mount Washburn. Near our camp were some groups of springs, which I described as follows in my report for 1872† (page 128):

Close to our camp there was a small gully containing some springs, of which I recorded the temperatures. A small stream ran through the gully, and throughout the entire bed there were springs whose presence was revealed by the bubbling of carbonic acid and sulphuretted hydrogen through the water. On either side of the stream there are abundant deposits, of a white color, containing lime, silica, and sulphur, giving evidence that at some past time this place was the seat of a large group of active springs, of which those now existing are a mere trace. It may not be many years before they will be entirely extinct. The specific description of these springs is as follows: No. 1 is 8 feet by 5, and gave off sulphuretted hydrogen abundantly. The temperature was only 52° F. No. 2 is 3 by 4 feet, and has a temperature of 53° F. Nos. 4 and 5 were merely small holes in the deposit on the bank of the stream. The temperature of the former was 94° F. and of the latter 115° F. The remaining springs were as follows: No. 6, 188° F.; No. 7, 188° F.; and No. 8, 190° F. The boiling-point here would be 198°.3 F. The temperature of the air during these observations was 76° F., the time being about 7.30 a. m. The elevation above sea-level was 8,117 feet. From this group of springs we caught a glimpse of a white spot through the trees, which indicated that there were more springs to the north of these. Toward this place we turned our heads, and while riding along through the woods we came to a pool of water which would measure probably thirty yards by fifty. The surface of the water was almost all in agitation from the number of points of evolution of carburetted hydrogen. The temperature of the water was only 54° F., while the air still remained at 76° F. This pool was on about the same level as the springs mentioned above. A short ride from this pool brought us to the spot we were seeking, and we found ourselves in the midst of an active group of mud springs or salses. The springs are distributed over the side of a hill which steams from top to bottom. It was a most horrible-looking place, and brought to our minds pictures of the infernal regions. The black and red colors of the mud and iron deposits gave the hill the appearance of having been burned, while here and there were masses of bright-yellow sulphur. The air was filled with the fumes of sulphuretted hydrogen. The noise made by the throbbing and pulsating masses of mud was continuous. This, with the splashing and spluttering of some of the springs, the plop-plop of the thicker mud, combined with the unearthly appearance of the scene, made us feel that we were on dangerous ground, and in walking about the springs we did so carefully, fearing that we might break through the crust. The mud in these springs is black in some, lavender-colored in others, and again yellow, while in consistency it is of all grades, from that of a thick mush to a mere inky-black water. In the thick-mud spring the steam seems to escape with an effort after several vain attempts. The mud rises in a hemispherical mass, falls and again rises, and after several repetitions the steam bursts from it, sometimes throwing the mud to a distance of 20 feet.

I divide the springs at this locality into two groups, the second group being some

*Lippincott's Magazine, July, 1880, page 33.
†Rep. of U. S. Geogl. Surv. of Terr. for 1872, 1873.

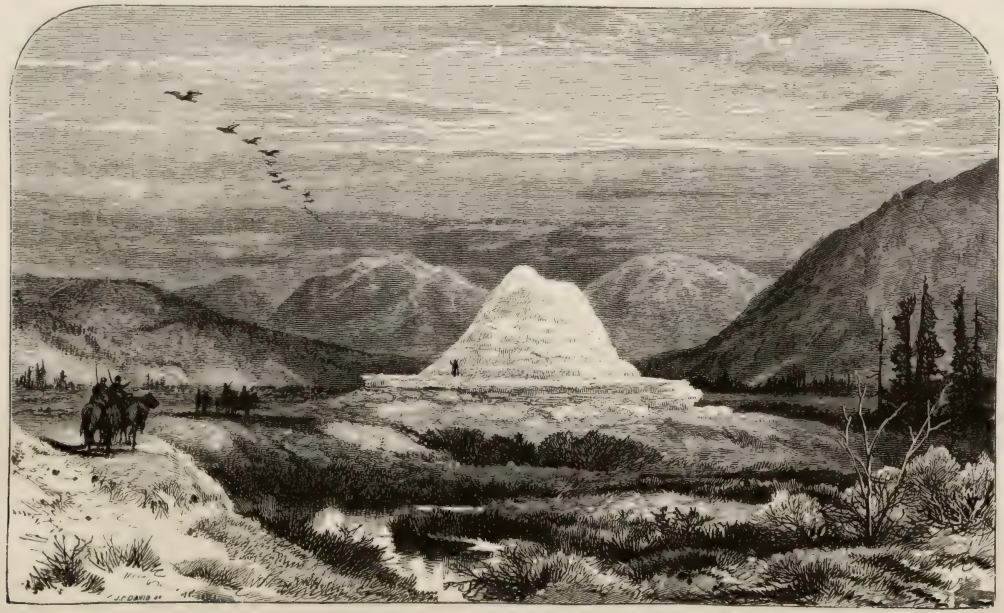


FIG. 2.—Soda Butte on East Fork of Yellowstone River.

distance higher up the hill. The following is the description of the springs in the first group: The first one contained a rather thin lavender-colored mud. It is a cavernous-like opening on the side of the hill, and is the topmost spring of about five springs that are situated in a line, one above the other, at different levels. There seems at one time to have been a fissure here which determined their position. It was the only spring of the five that could be approached, but the temperature even of this could not be taken on account of the steam coming from it. It was probably at the boiling-point. The mud was in active motion, and the steam came from it with a continuous roar. The spring also gave off sulphuretted hydrogen gas.

No. 2 was a large pool of muddy water, through which a number of steam jets forced their way, giving the spring the appearance of a sieve full of water, through the bottom of which the stream was forced. The temperature of the water was 194° F., and the air 78° F., the time of observation being about 9 o'clock in the morning. This spring was 30 feet above No. 1. Near it there was a spring of very thick, blue mud, the temperature of which I was unable to take, it not being safe to approach near it, as the mud on the banks was very soft.

A short distance to the right of No. 2, and a little above it, is No. 3, a large, yellow, muddy pool 30 feet by 50 feet in diameter, in which there was a great deal of bubbling, the water near the edge of the spring being especially agitated. The temperature was 140° F., the air remaining at 78° F. On the banks of this pool there was an abundant deposit of sulphur and alum. No. 4 is the most active spring of the group. It is about 20 feet higher up the hill than No. 3, and is about 30 feet in diameter, somewhat irregular in shape. The mud has formed a rim about it which is 2 feet above the spring on one side and 3 feet on the other. It contains a very thin blue-black mud, which is in violent ebullition, rising at times to the height of 3 and 4 feet. A dense column of steam, mingled with sulphuretted hydrogen gas, is continually escaping from it. I was able to take the temperature only at the edge, where I found it to be 190° F.; air, 78° F. In the center it was probably at the boiling-point, which at this elevation is 198°.2 F. About 20 feet below No. 4, and a little to the right, is No. 5. It is 15 feet long and 5 feet wide at the widest place, being somewhat triangular in shape. One edge of the bank overhangs the water and is coated with a deposit of sulphur, which is deposited by the sulphuretted hydrogen gas. The water here is clearer than in any of the surrounding springs. The center of the spring is in violent ebullition from the escape of steam. The temperature of the water at the edge of the spring was 184° F., the air being 78°. The second group has a general elevation of about 150 feet above the first, and is also situated on the slope of a hill.

No. 1 in this group was called the "Mush Pot." It is about 20 feet in diameter, and has three openings, each about 10 feet in depth. The mud at the bottom of these holes is very thick and of a bluish-black color. The mass heaves and throbs as the steam escapes through it. It was impossible to take the temperature of the mud, as the steam scattered it in all directions, rendering it impossible even to look into it with safety.

No. 2 was named the "Paint Pot," the mud in it resembling lead-colored paint. The entire surface was in violent agitation. The diameter of the spring is narrower at the top than at the surface of the mud, which was 8 feet below the surface of the ground. The mud is scattered in all directions, as in the last-mentioned spring, rendering it impossible to obtain its temperature. At intervals of about three minutes it seems to take a rest, remaining quiet for a few seconds.

No. 3 is a fissure of nearly 100 feet in length, in the course of which there are a number of black-mud springs, their average temperature being 185° F., while the air was 79° F. This fissure is about 100 feet above spring No. 1.

No. 4 is a similar fissure of about the same length. It is about 100 feet above the preceding one, and contains mud springs of the same character, the average temperature being 190° F. The boiling-point at this elevation is 197.6° F. All around this fissure there is an abundant deposit of sulphur and alum, the sulphur crystals being exceedingly brilliant and delicate.

No. 5 is a blue-mud spring of about 3 feet in diameter, having a temperature of 190° F.

Nos. 6, 7, 8, 9, and 10 form a small group distinguished by the abundance of sulphur surrounding them. The mud in them was very thick, and varied in color from blue to black. The ground about them was too treacherous to allow of a near approach, but their temperature would probably average about 185°–190°.

Besides the springs I have described above, there were numerous smaller ones, and a great many steam vents. I have only mentioned the most important springs. Both the groups are situated in banks of clay, and the deposits consist mainly of clay, alum, and sulphur. All the springs are acid in reaction from the presence of sulphuric acid. The sulphur results from the decomposition of the sulphuretted hydrogen which is so abundant in this locality. The oxidation of the sulphur and its union with the alumina and iron give us the alum which we find here.

Whether these springs are the ones indicated on the map or not I am unable to decide. My impression was that they were somewhat farther north. They are, I think, without doubt, the springs described by Lieutenant Doane* in his report, and by Dr. Hayden in the report of the survey for 1871.†

Captain Barlow also probably saw some of them, for he says:‡

While in the forest I came upon a valley of chalk-white rock, evidently an old system of warm springs; several small ones were still in operation, giving a perceptible warmth to a small stream flowing through the valley and filling the atmosphere with an intense odor of sulphur.

SPRINGS OF THE GRAND CAÑON.

It is scarcely to be doubted that the coloring which is so vividly displayed in the walls and slopes of the Grand Cañon of the Yellowstone is due to the presence of hot-spring deposits, as I indicated in my reports for 1871 and 1872.§ The yellows, which are so brilliant and widespread, are due to sulphur, and the reds to the oxidation of iron. The extent of these argues a greater prevalence of springs in the past. At present the springs are confined mainly to the bottom of the chasm, being found near the river's edge. The difficulty of reaching the bottom of the cañon has prevented their investigation except in a few instances.

Lieutenant Doane descended to the bank of the river, about 3 miles below the falls, in 1870. He says:

Selecting the channel of a small creek, and leaving the horses, I followed it down on foot, wading in the bed of the stream,‖ which fell off at an angle of about 30°, between walls of gypsum [?] * * * On entering the ravine we came at once to hot springs of sulphur, sulphate of copper, [?] alum, stream jets, &c., in endless variety; some of them of very peculiar form. One of them in particular, of sulphur, had built up a tall spire from the slope of the wall, standing out like an enormous horn, with hot water trickling down its sides. * * * After descending for 3 [?] miles in the channel we came to a sort of bench or terrace. * * * From here the creek channel was more precipitous, and for a mile we climbed downward over masses of rock and fallen trees, splashing in warm water, ducking under cascades, and skirting close against sideling places to keep from falling into boiling caldrons in the channel. After four hours of hard labor since leaving the horses, we finally reached the bottom of the gulf and the margin of the Yellowstone, famished with thirst, wet and exhausted. The river water here is quite warm, and of a villainously alum and sulphurous taste. Its margin is lined with all kinds of chemical springs, some depositing craters of Calcareous rock, others muddy, black, blue, slaty, or reddish water. The internal heat renders the atmosphere oppressive, though a strong breeze draws through the cañon. A frying sound comes constantly to the ear, mingled with the rush of the current. The place abounds with sickening and purgatorial smells.¶

Professor Bradley, in 1872, descended to the river level on the west side of the cañon over the slopes near the "Fall."

These slopes descend directly into the river, so that, even at the bottom, the utmost care must be used in walking. Along the edge of the river several small hot springs occur, which steam moderately, but rarely to such an extent as to be visible from the top of the cañon. I was able to reach but one of these, which had a temperature of 150°. On the opposite bank a miniature geyser was in operation; from the top of a steep cone, about a foot high, a half-inch stream was constantly spurting about a foot from the orifice.**

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* Yellowstone Expedition of 1870, p. 11.
† Report U. S. Geol. Survey for 1871, 1872, p. 86.
‡ Reconnaissance of Yellowstone River, p. 15.
§ Report U. S. Geol. Survey for 1871, p. 179. Report for 1872, p. 132.
‖ This is probably either Sulphur Creek of the map of the Park, or the small one south of it.
¶ Yellowstone Expedition of 1870, pp. 13, 14.
** Report U. S. Geol. Survey of the Terr., 1872, p. 233.

In 1871, in company with Mr. H. W. Elliott, artist of our party, after several ineffectual attempts, I reached the edge of the river, probably about a quarter of a mile below the falls.* Three or four small, warm springs were found on the brink of the water., They caused an abundant deposit of iron and gave off carbonic acid gas. A white organic [?] material was contained in the springs. Having no thermometers with us we could not determine the temperature, which we estimated at about 90°.

The small geyser cone mentioned by Professor Bradley is on the east side of the cañon, and is only one of the springs scattered along this side, although they cannot be followed along the bank of the river. Sulphuretted hydrogen is given off from nearly all of these springs. None of these are of much importance.

WAYSIDE GROUP.

This group of springs is situated on Broad Creek, and are described as follows by Dr. Heizmann:†

Six miles from Camp 40, on our trail, was found a group of springs in a ravine, the upper half of which was filled with extinct springs, where the water flowing through it was potable, the lower half, with active sources, greatly acidifying it. These were (contents, deposits, &c.) exactly like the last mentioned (Orange Spring Group). Farther on another group, similar to that about Turbid Lake, exists. A large central pond, water 100°, with an outlet giving a considerable flow toward a small creek, is surrounded by many small, clear, bubbling springs, with nearly the same variety of temperature (86°, 150°), and with the same deposits. Near it is a mud-hole (40 by 25 feet) in violent agitation, so much so that the mud in its center is sometimes thrown 2 to 3 feet into the air—great waves of mud being thrown with considerable force against and over its sides—but in other respects having the same characteristics as those at Turbid Lake.

ORANGE CREEK SPRINGS.

Under this head I shall quote the description of Springs near the head of Orange Creek, given by Dr. Heizmann, as he is probably the first one who has given any specific account of them. Prof. Comstock refers to them under the head of "Wayside Group and Isolated Springs."‡ His name, "Wayside Group," I shall give to another group in the same region, near the head of Broad Creek. Both of the groups are situated in a heavily-timbered region, east of the Grand Cañon of the Yellowstone, and have never been visited by any of our parties. They are not indicated on the map of the Park. Captain Barlow, in his trip from the "Falls of the Yellowstone" to the East Fork, probably saw some of the springs, but gives no specific description. He says§:

The whole region is filled with signs of warm-spring formation and brimstone basins, with occasional swamps of volcanic mud. * * * Beyond the next ridge was found another pretty stream, having a white, chalky bottom. Both (probably Orange and Broad Creeks) flow into the Grand Cañon of the Yellowstone. Steaming sulphur-jets were discovered on the banks of White Creek (Broad Creek?)

The following is Dr. Heizmann's description of the Orange Creek Springs, which are situated at about the forks of the creek:

We found a number of springs on the bank of Orange Creek, which, where we crossed, had a fine appearance, flowing rapidly between rocky and timbered hills, over a bright orange, siliceous bottom, though its valley is redolent with odors of sul-

*Report of U. S. Geol. Surv. of Terr., 1871, p. 179.

†Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, in 1873, 1875, p. 300.

‡*Ibid.*, p. 198.

§Senate Ex. Doc. No. 66, 42d Congress, 2d session, p. 40.

phurous gases. All of these differed in temperature; two of the largest, within a few feet of each other, were of 170° and 196°. The first (green-yellow deposit) sending a blackish water into the stream, contained iron and alumina, lime, sulphates, hyposulphites and sulphides, and silica, which last deposited in enormous quantities. The largest and most numerous steam-jets we saw in the Yellowstone region were found here, in a gap giving egress to a small stream arising from them, and flowing from the south into one of the forks of Orange Creek. Its sides and bottom, of deep red and yellow, included about 50 acres, and were filled with hundreds of steam-jets, but contained only a few small holes bubbling hot water. Over the greater portion of its surface the ground was very insecure, often breaking under the tread and exposing soft sulphur crystals, from the midst of which issued a new jet. Hard chips of sulphur, in very great quantities, are strewn about. Scattered in this gorge, on firm foundation, were rocks of all sizes, some 50 feet high, from beneath most of which violently puffed steam which deposited on the roofs sulphur crystals. There were two very large vents, whose action could be heard a great distance, that of throwing columns of steam from caverns half-way up the declivity, 200 feet into the air.

These, together with a few others not so large, emitted small, clear streams with variegated deposits, which united to form the main one through the gap. Water taken about 20 yards from the greatest jet, as near as one dared to venture, had a temperature of 144°, while the temperature of the steam issuing from the smaller and accessible vents was 196°; of the air, 59°. It contained iron and alumina, magnesia probably, and sulphates.*

Recapitulation of springs of Yellowstone River below Grand Cañon and on East Fork.

Name.	Number of springs.	Highest temperature.
		° F.
Junction Valley Springs	5 +	.....
Lower Creek Springs	3 +	127
East Fork Springs	3 +	.....
Washburne Groups	24	194
Grand Cañon Springs	8	150
Wayside Group	4	150
Orange Creek Springs	5 +	196
Total number of springs	47 +	.....

As far as known, there are no geysers in the springs enumerated above.

CHAPTER III.

HAYDEN'S VALLEY SPRINGS.

Hayden's Valley is about 10 miles from east to west and from 6 to 8 miles in a northerly and southerly direction, wider toward the west, along the course of the Yellowstone River. It marks the site of an old lake, a former extension of Yellowstone Lake, and the valley is underlaid by lake beds (sands and clays). As the result of the argillaceous and sandy character of the beds we have many mud springs in the valley. Sulphur appears abundantly also, probably due to the organic material that has been incorporated in the lake beds.

On an old map once seen by the writer, Coulter's route is laid down as passing through this valley, and the locality of Crater Hills is indicated. The first group described in this chapter might have been classed with those of the preceding one, but it really lies within the limits of the old lake basin. Wherever we have clear springs in this group it is probable that the clays have been removed from the sands or trachytes.

*Report of Reconnaissance of N. W. Wyoming, &c., by Capt. W. A. Jones, 1873, 1875, pp. 299, 300.

FOREST GROUP.*

This group of springs is located near the right wall of the Grand Cañon of the Yellowstone, near its head, and was so named by Professor Comstock, from its being nearly surrounded by timber. The springs were visited by one of our parties in 1871, and a sketch made by the topographer. The position of the springs is indicated on Mr. Holmes's geological map. Most of the springs are situated on a broad flat of sand, mud, and gravel. Mr. Schonborn's notes give temperatures ranging from 90° up to 190°. Dr. Heizmann gives a description of these springs as follows:

At camp 39, which was opposite the head of the cañon, were numerous extinct and active springs, the latter materially aiding in the formation of a clear, rapid stream (70°), which was very acid and astringent, depositing reddish yellow, and running by a great mound-shaped bank containing both the active and extinct springs. Its water, taken from below all its sources, contained only iron and alumina, sulphates and chlorides. It is formed by several groups of springs about camp 39, closely allied, judging by the great prevalence in all of iron and alum. Two springs in one set north of us (156° and 158°), each 4 or 5 feet in diameter, muddy, bubbling contents, with no outlet visible, emitting a strong odor of sulphuretted hydrogen, and ejecting with it sulphurous acid gas, contained lime, iron, and alumina, magnesia, sulphates, sulphides, chlorides, and hyposulphites. They are surrounded by countless springs and mud vents of all temperatures. The contents of one of the latter, a very large one, are colored like molasses, and have in agitation a curious, intermittent, thudding sound. Of the others the shades are as various as their temperatures—black, mud and lead, light and deep green, colorless, &c. Six of those with light-green water (88°–100°) having an outlet and very acid, gave only reactions for iron, alumina, magnesia (abundant), sulphates, sulphides (slightly). Two in the same group had water, blackish (deposit drab-green), boiling (170°) and bubbling so violently in deep oblique holes as to be thrown out in great waves, slightly acid, and containing iron and alumina, sulphates and sulphides. The sulphur was hardly appreciable after the water was taken out, but together with hyposulphites was deposited in great quantity.

Another group, separated from the last by a small ridge filled with the remains of springs and apparent geysers, possessed not so many springs, but all of the same kind excepting one (140°), which had a colorless water, more acid than any tested, and contained iron, alumina, sulphates, and sulphides (slightly). All of these springs tested emitted sulphuretted hydrogen, (some steam and sulphurous acid gas), the deeper colored the greater quantity, but none evolved carbonic acid gas. The deposits of all contained silica in various, though small, proportions.

Professor Comstock, speaking of the group, says:

This group comprises representatives of all the great classes of thermal springs, including also a variety of cold springs of varying composition and temperature; while, as a whole, the locality in which they occur may be said to belong to one of the latest stages of thermal intensity. * * * The majority of the active springs, including the salses and solfataras, emerge through the enormous accumulations of ancient hot-spring deposits, which here almost completely obscure the underlying beds of volcanic origin. * * * One feature of several of these mud bowls is especially noticeable, *i. e.*, the thickness or toughness of the mud, which causes it to be arranged in the form of low cones about the centers of ebullition. This represents the stage of tansition from the salse proper to the mud puff, but none of the latter were observed in the basin occupied by the Forest Group.

CRATER HILLS.

As has been indicated in another portion of the report, the rounded hills which mark this locality were laid down on some of the earlier maps. On Raynolds's map it is called Sulphur Hill. The hills, which were called "Seven Hills" by the Washburn-Doane party in 1870, are composed in part of spring deposits and trachyte tuff. For the geology of this region the reader is referred to Mr. Holmes's report. There are only two hills, instead of seven; one is 150 feet in height, and the other about 140 feet. No temperatures were taken in 1878, and the following description is made up mainly from the reports of 1871 and 1872.

*This is the title given by Comstock in Jones's Report, p. 197.

Yellow Sulphur Spring (Plate VI *b*).—This is the principal spring of the group, and the one that first claims the attention of every visitor, as it is characterized by the escape of great volumes of steam and is generally in violent ebullition. Dr. Hayden, in the report for 1871 (p. 89), thus describes this spring:

On the south side of these hills, close to the foot, is a magnificent sulphur spring. The deposits around it are silica; but some places are white, and enameled like the finest porcelain. The thin edges of the nearly circular rim extend over the waters of the basin several feet, yet the open portion is 15 feet in diameter. The water is in a constant state of agitation. The stream that issues from this spring is so strong and hot that it was only on the windward side that I could approach it and ascertain its temperature, 197°. The agitation seemed to affect the entire mass, carrying it up impulsively to the height of four feet. It may be compared to a huge caldron of perfectly clear water somewhat superheated. But it is the decorations about this spring that lent the charm, after our astonishment at the seething mass before us—the most beautiful scalloping around the rim, and the inner and outer surface covered with a sort of pearl-like bead-work. The base is the pure white silica, while the sulphur gave every possible shade, from yellow to the most elegant cream. No kind of embroidering that human art can conceive or fashion could equal this specimen of the cunning skill of nature.

In 1870 Lieutenant Doane observed it, and speaks of it in his report as follows:

It measures 15 by 20 feet on the inside. The water boils up constantly from 3 to 7 feet in height, the whole surface rising and falling occasionally with a flux and reflux of 4 feet additional, overflowing its basin and receding every few minutes. The basin is built up with a solid rim or lining of pure crystalline sulphur (?) 4 feet in width all around the edge, probably amounting to 40 tons in weight. The water is clear, but of a whitish cast, and above the boiling point, steam being evolved from its surface. The basin cannot be approached nearer than 20 feet distant on account of the scalding vapors. A small channel leads down the slope, and for several hundred feet its bed is incrusted with a sulphur deposit, showing that the spring occasionally flows a considerable quantity of water. The deposit is from 3 to 10 inches deep.

In Dr. Hayden's description the temperature is given as 197°. The same year I found it to be 183½°, which is the temperature obtained by Mr. Schonborn and placed on his chart in the report for 1871. In 1872 the temperature obtained was 178°F. These variations are due partly to the fact of differences in the spring at different times and partly to the fact that the temperature at the edge is different from what it is in the center. We passed the spring in 1878 and found that it presents the same characters it did in 1871 and 1872. The steam jet, however, which we noticed in 1871 and 1872 quite close to this spring did not appear to be in action.

Turbid Blue Mud Spring.—This is near the Large Sulphur Spring, and in 1871 had a temperature of 164° F., and in 1872 163° F. It has a basin about 35 feet in diameter, and its contents are rather thin muddy water than mud. It is acid in reaction, and tastes of alum.

South of the springs just described is a basin filled with innumerable mud-puffs, sulphur holes, and steam-vents. Lieutenant Doane, on page 16 of his report, thus describes them:

The mud ejected is of different degrees of consistency, but generally about the thickness of common mortar, and mostly of an iron-brown color. It boils slowly like hush, with bubbles of gas escaping, and is spouted to various heights, from 2 to 40 feet, falling with dull splashes around the edges of the craters, which are being built up continually and continually caving in, to be worked over and ejected as before. Some of the springs throw up yellow mud, others white, and a few pink. The different springs of all classes had no apparent connection with each other, though often but a few feet apart; the mud being of different colors, the basins having different levels, and the pulsations being independent, one being frequently in violent ebullition while another near by was quiescent. A plasterer would go into ecstacies over this mortar, which is worked to such a degree of fineness that it can be dried in large lumps, either in the sun or in a fire, without a sign of cracking, and, when once dry, is a soft, finely-

grained stone, resembling clay slate when dark, or meerschaum when white. Mortar might well be good after being constantly worked for perhaps ten thousand years.

The principal mud spring in this subgroup, the "Blue Mud Pot," is graphically described by Dr. Hayden as follows:

One of them has a basin 20 feet in diameter, nearly circular in form, and the contents have almost the consistency of thick, hasty pudding. The surface is covered all over with puffs of mud, which, as they burst give off a thud-like noise; and then the fine mud recedes from the center of the puffs in the most perfect rings to the side. This mud-pot presents this beautiful picture; and although there are hundreds of them, yet it is very rare that the mud is in just the condition to admit of these peculiar rings. The kind of thud is, of course, produced by the escape of the sulphuretted hydrogen gas through the mud. Indeed, there is no comparison that can bring before the mind a clearer picture of such a mud volcano than a huge caldron of thick mush. The mud is so fine as to have no visible or sensible grain, and is very strongly impregnated with alum. For 300 yards in length and 25 yards in width the valley of this little branch of Alum Creek is perforated with these mud-vents of all sizes, and the contents are of all degrees of consistency, from merely turbid water to a thick mortar. The entire surface is perfectly bare of vegetation, and hot, yielding in many places to a slight pressure.

The mud spring described had a temperature of 180° F. The following table, taken from my report for 1872, gives the remainder of the springs in this subgroup at Crater Hills:

No.	Size of spring.	Temperature of spring.	Temperature of air.	Remarks.
1	A collection of springs covering an area of 600 square feet, and varying in size from one to three inches in diameter.	174° F.	59° F.	The water in this collection of springs has a milky hue, and the noise made by them resembles that made by a number of pots boiling simultaneously.
2		176	59	
3		182	59	
4		186	59	
5		144	59	
6		160	59	
7		168	59	
8		150	59	
9		160	59	
10	3 feet diameter	80	59	White-sulphur spring.
11	8 feet diameter	148	59	Clear spring.
12		176	59	Thick greenish-mud spring.
13	2 feet diameter	180	59	Yellow-mud spring in active ebullition.
14	8 × 2 feet	90	59	A turbid pool bubbling at the edges.
15		162	59	A collection of greenish-sulphur springs, each a few inches in diameter.
16		166	59	
17		182	59	
18		178	59	
19		108	59	
20		180	59	This spring was called Foam Spring last year.
21	2 × 4 feet	170	59	Bluish muddy water.
22	10 × 3 feet	188	59	Both these springs have lavender-colored mud and No. 2 is in active agitation.
23	2 feet diameter	180	59	
24	These springs occupy a space of about 1,200 square feet.	150	59	This collection of springs varies is size from a few inches to four feet. The water in the majority is of a milky hue. In others it is yellow or lavender-colored, and in some it is transparent.
25		184	59	
26		130	59	
27		170	59	
28		168	59	
29		184	59	
30		106	59	
31		154	59	
32		188	59	
33		160	59	
34		130	59	
35		162	59	
36		174	59	
37		128	59	
38		120	59	
39		106	59	
40		176	59	
41		146	59	
42		186	59	
43		168	59	
44		174	59	
45		178	59	
46		172	59	
47		90	59	
48		158	59	
49		170	59	

The following table gives the comparison of the temperatures taken in the two years, and completes the list of springs in this locality:

Name.	Size.	Temperatures in 1871.	Temperatures in 1872.
		°F.	°F.
Yellow Sulphur Spring	12 to 15 feet diameter	183½ to 197	178
Locomotive Jet	Opening 6 inches diameter	191	.....
Steam Jets, near Sulphur Spring	.....	197½	.....
Turbid Blue Mud Spring	45 feet by 60 feet	163	104
Blue Mud Pot	4 feet by 10 feet	188½	.....
Sulphur Spring (east of hills)	.....	130	.....
Sulphur Spring (in north part of hills)	.....	140	.....

The deposits at Crater Hills are mainly siliceous, but sulphur is a characteristic of many of the springs, and the springs therefore give acid reactions. An analysis made in 1872 of a specimen from the Yellow Sulphur Spring gave 3.23 per cent. of sulphur after 23.48 per cent. of water had been expelled by ignition.*

The surface surrounding the springs, at many places, consists merely of a crust, and the under side as is shown on breaking it is coated with crystals of sulphur. Nearly all the springs give off sulphuretted hydrogen gas. The deposits of alum are due to the action of the sulphurous waters upon the alumina and iron in the clay banks through which the acid waters pass on their way to the surface. The small stream which carries the water from these springs is strongly impregnated with alum. This creek is known in the reports for 1871 and 1872 as *Alum Creek*, but on the map of the Park in this volume the *main* stream of the valley, which enters the Yellowstone a short distance below, is called *Alum Creek*. On the map accompanying Comstock's report this is called Warm Spring Creek. Iron is also present in the springs, as the weathered deposits show; the red stains on the *white hills* being one of the characteristic appearances. The area occupied by the remains of extinct springs is much larger than that occupied by those that are now active.

On the east side of the Yellowstone, opposite Crater Hills, there are sulphur springs along the edge of the hills, but none of any importance until the mud volcanoes are reached. They are not indicated on the map.

MUD VOLCANOES OR MUD SPRINGS.

This locality, which is designated on the maps as Mud Geysers, is 4 miles below Yellowstone Lake and 6 miles from Crater Hills. It is the point from which Howard's wagon road starts for the East Fork of the Fire Hole or Madison River. Its name designates the character of its springs and salses. The name "Mud Volcanoes" is taken from the fact that one of the principal springs here is the Giant's Caldron or Mud Volcano. Besides this there are a number of mud springs with craters like miniature volcanic craters. Besides the Mud Volcano there is here a muddy sulphur geyser, which is the first geyser met with by parties entering the region via Bozeman Botteler's and the Mount Washburn route. I prefer to keep the name by which I designated the locality in 1871 and 1872.

The springs occupy an area of about three acres, and are found in ravines and gullies cut into sandstones which were deposited when Yellowstone Lake spread over the entire area of Hayden's Valley.

These at the base are rather coarse, as shown in the exposures along

*Report for 1872, p. 137.

FIG. 3.—Chart of Springs at Crater Hills, 1871.

the river. In some places these sandstones appear to have been infiltrated with the siliceous waters which has given them a vitreous appearance. Above these sandstones are finer-grained ones, as shown at the Grotto (No. 12.), and on the surface are clays. When the water passes through these we have the mud springs. When it emerges from the sandstones it is clear, as in the Grotto, or simply turbid as in some of the springs near the river's edge. As I pointed out in my report for 1871 (page 181), the difference in the springs is due to the character of the rock through which the water has to pass.

Every possible variation is to be found in the contents of the mud pots; some are simply muddy water, others are like kettles of boiling soap; some like caldrons of mush or paint, and still others like stiff mortar. The supply of water has a great deal to do with the consistency of the mud. In a wet season, when the surface supply is greater, the mud will be thinner. It is of all colors—red, pure white, like meerschaum when it is dried, lavender, gray, or blue. Nearly all the springs give off sulphuretted hydrogen, and silver watches carried by members of the party soon showed the effect of the sulphurous gases. The quiet pools are generally sulphur pools, some of them of large dimensions. Besides the springs there are many steam vents, whose holes are lined with sulphur crystals. The mud volcanoes have generally a circular pit about 10 feet deep, with a rim or mound on the outside raised several feet above the general level. Such a spring may begin simply as a clear spring, into which the earth falls. The steam gradually works this up with the water, and it is a mud spring. It may become thicker by the caving in of the sides, although the evaporation of the water is the cause in most of the cases. After a time the spring may become choked, and we have one of the many dead holes seen among the active springs.

I shall now give full descriptions of the three principal springs, which are the Geyser, the Mud Volcano, and the clear boiling or pulsating spring (Grotto). The rest of the springs will be given in a table following, in which a few additional points will be given briefly.

Mud Geyser (Plate VIc).—This is the principal object of interest at the mud springs locality, and is easily recognized by its depressed basin, which measures 150 feet by 200 feet, and is 8 feet deep. In this the basin proper, or crater of the geyser is about 60 feet in diameter, surrounded by a rim that slopes inward at an angle of 30° to a funnel-shaped orifice. This is seen projecting above the water in the picture (Plate VIc), just to the right of the fountain-like mass. Between this crater and the rim of the outer basin there is a deposit of clay and silica which has hardened and resembles a very fine clay-slate. It has been deposited by the water of the geyser. The outer rim is broad and mound-like, and has a channel cut through it by which any surplus water is carried from the basin, although ordinarily there is no overflow from the geyser. This is shown in the foreground of the illustration. On the west side of the basin, near the crater, there is a steam vent, and in the south end two springs, or spring-basins, for there are numerous springs. When the outer basin is filled, the outlines of these springs as well as that of the geyser crater are not distinguishable. These springs appear to be perfectly independent of the geyser in their action.

In order to show the changes that have taken place in the geyser since it was first described, I will present the characteristics described each year.

1870.—Lieutenant Doane describes this geyser in his report and gives an account of its eruptions, as follows:

This was a periodic geyser, having eruptions every six hours, and in the following manner: The crater being full of boiling water, and the vapor vent active, suddenly

columns of steam shoot up through the water to the height of 300 feet. The ground trembles, the vapor hisses through the vent with increased force. The water of the crater is violently agitated, being thrown up in vast columns to the height of 30 and 40 feet, splashing out as far as the rim of the basin with great force. This continues for half an hour, the water increasing in quantity in the crater all the while. Then the steam ceases suddenly to escape, the water settles, and commences to lower in the crater, continuing to fall to the depth of 35 feet, leaving bare the incrusted and funnel-shaped walls, which converge at that depth to the diameter of 7 feet. The water here stands for a time, the steam jets cease to hiss, the vapor vent to give forth its fumes, and all is quiet. After the lapse of an hour, the water stoutly rises again, the vents become active, and at the end of the regular period the whole performance is repeated as before.

1871.—We spent a couple of days at the Mud Volcanoes in 1871 and no*ed a numer of eruptions. In the report for 1871 I described the eruption briefly as follows:

Soon, however, there began a slight bubbling in the center, and the water began to rise gradually in the basin until suddenly it was thrown into violent agitation, the contents becoming very muddy. Immense volumes of steam escaped, throwing the water to the height of 20 feet. The eruption lasted about a quarter of an hour, when it ceased as suddenly as it began, and the surface of the water was more placid than before. This eruption took place eight times in twenty-six hours.

After we left the locality, Mr. Carrington was sent back to observe the geyser, and his report is found in Dr. Hayden's report. He says:

We arrived at the mud geysers ten minutes after 9 o'clock a. m., July 1. [This is a misprint; it should be August 1.] The pool was calm, with exception of the little boiling bubbles that are always on its surface. In circumference it measures nearly 100 feet. While selecting a place to camp, unsaddling our horses, &c., we heard a loud, hissing noise, as an escape of steam. Hurrying to the geyser, I saw a wave about three feet in height rise and die away to the left; three similar ones followed in quick succession. It then, with a dull, heavy sound, accompanied by dense columns of steam, suddenly burst up to a height of 20 feet. It continued in action for the space of fifteen minutes, when it ceased flowing as suddenly as it had commenced. The average height of this flowing was about 15 feet, although some jets reached fully 30. Five minutes after the eruption, the pool measured 25 feet in circumference and 3 feet in depth, where before it was 100 feet in circumference and 11 feet in depth. Ten minutes after (at 9.45 a. m.), I noticed that it was slowly commencing to rise again. It continued to do so until twenty minutes after one (1.20 p. m.), when it began to boil near the center, a black formation making a ring around the boiling part. This boiling gradually increased in violence, lasting twenty minutes; it then suddenly stopped, and a wave 2 or 3 feet in height arose, dying away to the left, and the flowing then took place as before described. Average height of this flowing, 15 feet; duration, 20 minutes.

I tabulate the eruptions witnessed by Mr. Carrington, so that they may be compared with those of 1872.

Date.	No. of eruption.	Length of eruption.	Interval between beginnings of eruptions.	Interval between end and beginnings.	Height.
1871.		*M.*	*H.M.*	*H.M.*	*Feet.*
August* 1	1	15	.....	.....	15 to 30
1	2	20	4 10	3 55	
1	3	15	3 30	3 10	
1	4	20	3 30	3 15	
1	5	15	4 00	3 40	
2	6	15	3 30	3 15	
2	7	15	3 30	3 15	
2	8	10	3 30	3 15	

*This, in the original notes, is July, which is a misprint.

1872.—In 1872 I spent about two days and a half at mud volcanoes, and noted eight eruptions of the Mud Geyser, although they were not

MUDDY GEYSER IN ACTION 1871 MUD VOLCANOES

consecutive as those of 1871 were. As my description of the eruption as witnessed in 1872 contains some additional particulars to those already given, I transcribe it from the report of 1872 (pp. 128–140).

The following is the description of an eruption: The water gradually rises until the inner basin is filled, when there is noticed a bubbling in the center. Suddenly, without any further warning, it becomes violently agitated and an immense mass of muddy water, mingled with clouds of steam, is thrown into the air. This action lasts a few minutes and is followed by a lull, the action not ceasing entirely. Then it recommences with renewed violence, and the water fills the entire outer basin, the water striking the banks in a succession of waves. The water is thrown up in a succession of impulses that follow each other rapidly, and sometimes the water is thrown obliquely, and seems as though it would overwhelm one standing on the bank. The mass of water and mud is immense. After the maximum height is obtained the jets become smaller and smaller, and the eruption ends as suddenly as it began. It is a very impressive sight, and the stopping is like a calm after a storm. The water of the geyser is very muddy, and bluish in color, having an acid reaction, due to the presence of sulphuric acid.

I will transcribe my field-notes below and then give the result in a tabulated form, so that the whole may be placed before the eye at once.

August 11.

4.02 p. m.—The temperature of water in the basin is 140° F. and the air 50° F.

4.37 p. m.—The water is rising rapidly and there is considerable bubbling in the center of the basin, the temperature remaining the same.

4.42 p. m. to 4.52 p. m.—The water is still rising and flows in currents, giving it a variable temperature of 140° F. to 180° F.

5.02 p. m.—The temperature is still 180° F. at the edge, although in the center it must be considerably higher. It is still in ebullition.

5.04 p. m.—The eruption commences.

5.10 p. m.—There is a lull in the action.

5.14 p. m.—The maximum (40 feet) is attained.

5.17 p. m.—The eruption ends and the water at the edge of the basin has a temperature of 172° F.

5.52 p. m.—Temperature of water is 148° F. and the air 48° F. The water is 4 feet lower than it was during the eruption, and the sides of the basin are shown sloping inward. Several steam vents, not seen before, are now made apparent. The surface of the water is quite placid, save in the center, where a slight bubbling takes place. The water seems to be rising slowly.

6.37 p. m.—The water has risen 1 foot since the last observation, and is still rising.

7.37 p. m.—The water is now 6 inches above the level last observed.

9.35 p. m.—The eruption commences.

9.48 p. m.—The eruption ends. The maximum height was estimated at 20 feet, it it being too dark to take any angles.

August 12.

6.19 a. m.—The geyser has evidently had an eruption during the night. The basin is full and the center in ebullition.

6.31 a. m.—The eruption commences.

6.35 a. m.—There is a lull.

6.42 a. m.—The eruption ends. The maximum height was 25 feet, and I noticed that the ground shook beneath me while the eruption was going on.

10.19 a. m.—The temperature of the water at the edge of the basin is 148° F. and the air is 60° F. The center is bubbling, and a black, oily substance floats on the surface.

10.29 a. m.—The temperature of the water is from 140° F. to 180° F., and is rapidly filling the basin.

10.49 a. m.—The eruption commences.

10.55 a. m.—There is a lull.

10.58 a. m.—The maximum (18 feet) is attained.

11.02 a. m.—The eruption ends.

11.08 a. m.—The temperature at the edge of the basin is 170° F.; air, 60° F. The water has fallen a foot already.

11.15 a. m.—Water, 150° F.; air, 60° F. The water has fallen 18 inches.

11.20 a. m.—The water has fallen 5 inches since the last measurement.

11.24 a. m. to 11.29 a. m.—The water still has a temperature of 150° F., and has fallen 2 feet 10 inches

11.39 a. m.—The water has fallen 3 feet 2 inches since the eruption ceased (lowest point).

11.49 a. m.—The water is rising slowly.
2.39 p. m.—The water is within 1 foot of the top of the basin and bubbling in the center. Its temperature near the edge is 146° F., the air still being 60° F.
3.14 p. m.—Temperature outside the rim of the basin is 125° F.
3.15 p. m.—The eruption commences.
3.21 p. m.—There is a lull.
3.25 p. m.—The maximum (22 feet) is reached.
3.27 p. m.—The eruption ends. Temperature of water at edge of basin 170° F.
7.39 p. m.—The eruption commences.
7.44 p. m.—There is a lull.
7.48 p. m.—The maximum (19 feet) is reached.
7.51 p. m.—The eruption ends.
Mr. Sloane took observations of two eruptions on August 9, as follows:
12.40 p. m.—Eruption commences.
12.47 p. m.—Lull.
12.49 p. m.—Maximum estimated at 25 feet.
12.52.30 p. m.—Eruption ends.
4.58 p. m.—Eruption commences.
5.04 p. m.—Lull.
5.07 p. m.—Maximum estimated at 30 feet.
5.11 p. m.—Eruption ended.

The table following is practically the same as that given in the report for 1872, the difference being that the one now given contains some additional points not included in the one for 1872:

Date.	No. of eruption.	Length of eruption.	Interval between commencement and lull.	Interval between lull and maximum.	Interval between beginnings of eruptions.	Interval between end of one and beginning of next eruption.	Maximum height.	Temperatures.
1872.		*M. S.*	*M.*	*M.*	*H. M. S.*	*H. M. S.*	*Feet.*	° *F.*
August 9	1	12 30	6	3	.....	.....	25	
9	2	13 00	6	3	4 18 00	4 05 30	30	
11	3	13 00	6	4	.....	.....	40	180 just before.
11	4	13 00	.....	.....	4 31 00	4 18 00	20	
12	5	11 00	4	.....	.....	.....	25	
12	6	13 00	6	3	4 20 00	4 07 00	18	180 just before.
12	7	12 00	6	4	4 26 00	4 13 00	22	170 at end.
12	8	12 00	5	4	4 24 00	4 12 00	19	

Comparing this with the table for 1871 it will be seen that the length of the eruption is less by several minutes (2 to 5) and that the intervals between the eruptions is greater.

The following table compares the averages of the two years:

	1871.	1872.
Average length of eruptions	15*m.* 37½*s.*	12*m.* 26. 75*s.*
Average intervals between ends and beginnings	3*h.* 15*m.*	4*h.* 11*m.* 6*s.*

It must, however, be remembered that these averages are derived from comparatively few observations.

1873.—As far as I can learn no observations were made in 1873, as Professor Comstock passed down the right bank of the river and did not therefore see the "Mud Geyser."

1874.—The Earl of Dunraven saw two or three eruptions, but gives no particulars,* except to say that they lasted about 10 minutes and

* The Great Divide: Travels in the Upper Yellowstone in the Summer of 1874, by the Earl of Dunraven, London, 1876, p. 247.

reached a height of 20 to 30 feet. On his first visit he found the water receding, and was obliged to leave before the eruption took place.*

1875.—Captain Ludlow in his report describes the eruption of the geyser in 1875:†

> About 4 p. m. pistol shots from the Mud Geyser summoned us to witness an explosion. The water had risen gradually until the smaller springs were submerged and the basin enlarged to its full dimensions. Near the center, the geyser was boiling and bubbling actively, and soon spurted to a height of 5 or 6 feet, falling and rising again, and after about three minutes of excitement subsided, the water lowered, being gradually swallowed down the several orifices, and the discharge was over. The geyser has a period of about 4½ hours, and several of the subsequent eruptions were witnessed. None exceeded 10 or 15 feet.

1876 and 1877.—I can find no record of any observations for 1876, but in 1877 General Sherman's party visited this locality and saw the geyser in action. Col. O. M. Poe, of his party, says:

> It has an interval of somewhat more than an hour, and rises above the ordinary level to a height of 5 or 6 feet, with considerable disturbance.

1878.—We arrived at the Mud Springs or volcanoes on the afternoon of the 26th of September, and left on the morning of the 29th, and during this time the basin of the Mud Geyser whenever seen was full of water, so that the inner hard basin or bowl was not seen. The water also covered springs 2 and 3, which in 1872 were seen to be independent. A great many points of ebullition were noticed over the crater of the geyser, and the steam vent alongside of the geyser in the bank contained water through which the steam escaped with a thumping sound.

On September 27 I saw an eruption which began at 9.29 a. m. It consisted only of a bulging of the mass of water, which attained a height of perhaps 3 feet in a surging, splashing mass, muddying the pool surrounding. The water in the latter was thrown into waves. This eruption ended in 1 minute and 15 seconds, and the water did not recede as in the eruptions seen in 1871 and 1872. The temperature in the basin was 127° F., but this temperature was on the edge, as it was impossible to reach to the central orifice.

It is difficult, in view of the limited data we have, to determine whether this geyser is declining in activity or not. Just before our visit there had been a great deal of snow and rain, which probably had something to do with the filling of the basin, and may have diminished the apparent activity. We really know nothing of the effects of the variations in the supply of water upon the geysers and hot springs. There is no doubt, however, that the greater the body of water supplied by rain and snow the lower is the surface temperature. Those taken this year were much lower than the ones taken in 1871 and 1872. In the temperature of those years a decrease of 11° was noted from 1871 to 1872. It seems probable therefore that there has been some actual decrease in the activity of the Mud Geyser. Lieutenant Doane speaks of the action lasting half an hour in 1870. In 1871, as we have seen, the duration was about 15 minutes, which in 1872 had decreased to 12 minutes, and in 1875, according to Captain Ludlow, it was only about 3 minutes. In 1878 the eruption I witnessed was only 1 minute and 15 seconds in length. It is possible of course that there is an irregular regularity which will have to be determined by future observations. The height to which the geyser spouts also appears to be diminishing. In 1870 it was 30 feet or 40 feet; in 1871, 15 feet to 30 feet; in 1872, 18 feet to 40 feet; in 1875, 5 feet to 15 feet; and in 1878 only about 3 feet at the one time noted.

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* The Great Divide, p. 237.

† Report of Reconnaissance from Carroll Mountains to Yellowstone Park, 1875, p. 24.

N. P. Langford, speaking of the change from 1870 to 1872, says:

The jet of the Mud Geyser was thrown with greater force [in 1870] and to a loftier height, and its basin, but partly filled in 1870, now overflowed whenever an explosion occurred.*

I am inclined therefore to think that there has actually been a decrease.

Giant's Caldron or Mud Volcano.—This is perhaps equally interesting with the Mud Geyser. Its crater or excavation is about 25 to 30 feet in diameter and 20 to 30 feet deep, situated on the slope of a wooded ravine. The deposit surrounding it is a dark gray mud, consisting mainly of alumina. The contents consist of thin blackish mud in a state of constant ebullition, and from its surface a column of steam escapes with such volume that it can be seen for miles. This mud spring has given name to the locality, and was first seen by the Washburn party of 1870. I shall give the descriptions chronologically, as in the case of the Mud Geyser.

1870.—Lieutenant Doane describes the Mud Volcano as follows:

Heavy volumes of steam escaped from the opening, ascending to the height of 300 feet. From far down in the earth came a jarring sound, in regular beats of five seconds, with a concussion that shook the ground at 200 yards distant. After each concussion came a splash of mud, as if thrown to a great height; sometimes it could be seen from the edge of the crater, but none was entirely ejected while we were there. Occasionally an explosion was heard like the bursting of heavy guns behind an embankment, and causing the earth to tremble for a mile around. These explosions were accompanied by a vast increase of the volumes of steam poured forth from the crater. This volcano has not been long in operation, as young pines, crushed flat to the earth under the rim of mud, were still alive at the tops. The amount of matter ejected was not great, considering the power of the volcano. The distances to which the mud has been thrown are truly astonishing. Directly above the crater rises a steep bank, a hundred feet in height, on the apex of which the tallest tree near is 110 feet high. The topmost branches of this tree were loaded with mud 200 feet above, and 50 feet laterally away from the crater. The ground and fallen trees near by were splashed at a horizontal distance of 200 feet. The trees below were either broken down or their branches festooned with dry mud which appeared in the tops of trees growing on the hillside from the same level with the crater, 50 feet in height, and at a distance of 180 feet from the volcano. * * * It was with difficulty that we could believe the evidence of our senses, and only after the most careful measurements could we realize the immensity of this wonderful phenomenon.†

1871.—We had no difficulty in recognizing the Mud Volcano in 1871. A dense column of steam constantly escaped from the orifice, and it was only when a puff of wind blew it aside that we could look into it and see the seething contents, 30 feet below the surface. No eruption took place during our stay. The steam poured forth with a steady roar. The coating of the trees with mud was noticed, and small pines were seen still alive within 10 or 20 feet of the orifice. We still supposed that eruptions of mud occurred, but concluded that they must occur at long intervals.

1872.—The Mud Volcano appeared to be in much the same condition as in 1871. Mr. Langford, who had not seen it since 1870, however, saw great changes in it. He says:

The crater, which in 1870 was in a state of constant ebullition, the report which resembled the noise of distant artillery, the cone which had been builded by a constant accretion of varied deposits, all had disappeared. A large excavation remained, and a seething, bubbling mass of mud, with several tree-tops swaying to and fro in the midst, told how terrible and how effectual must have been the explosion which produced such devastation. I could not realize that in this unsightly hole I beheld all that was left of the rarest of those physical wonders which filled this extraordinary region.‡

* Scribner's Magazine, Vol. VI.

† Yellowstone Expedition of 1870. Senate Ex. Doc. No. 51, 41st Congress, 3d session, pp. 17, 18.

‡ Scribner's Magazine, Vol. VI.

All the time we were at the locality we saw no eruption of mud, and still the coating of the trees appeared to go on. This led to investigation, which appeared to prove that the mud is carried up mechanically instead of being erupted. The following on the subject is taken from my report for 1872:

Last year, when at this locality, we noticed that the trees near the Giant's Caldron had their branches coated with mud, and the question was raised as to how the mud got there; we concluded that the geyser sometimes ejected its contents. This year, however, investigation seemed to prove that the mud is carried up mechanically, mixed with the steam that is constantly rising from the caldron, and that the spring never has any eruptions. We were led to this opinion first by noticing that it was only the under side of the branches that held the mud. Mr. Holmes then placed some dead branches in such a position that the steam came upon them, and in a few hours they had a coating of mud. Again, some of the trees on which the branches are coated are living, which would hardly be the case had they received the mud from an eruption. Another reason also is found in the fact that the surface of the spring is constantly agitated, which is rarely or never the case with a true geyser. Still, in the past it may have been a geyser and had regular eruptions.*

1873.—Professor Comstock of course did not see the caldron, as he was on the opposite side of the river, but he evidently noticed the column of steam from it. He says:

Dense clouds of vapor may be seen issuing from these localities at certain hours, and the thumping noise produced by the throbbings of the agitated mud of the salses may be distinguished without difficulty at a considerable distance.†

1874.—The Earl of Dunraven refers as follows to the Giant's Caldron:

This caldron is filled with thin mud in a state of most fearfully wild commotion, boiling, spitting, and spluttering like a pot full of stirabout screeching hot. The roar of it can be heard at a considerable distance, and the steam of it ascends in a dense column to heaven. A slight smell only of sulphureted hydrogen is noticeable here, but with many of these mud springs not only does the steam ascend to heaven but the stench also.‡

The condition of the spring in 1874, therefore, appears to be about as it was in 1871 and 1872. The steam still escaped with a roar. Ludlow, in 1875, makes no mention of the caldron.

1878.—We noticed little if any change. Perhaps the noise made by the escape of the steam is not so great, but the column is still dense enough to prevent our getting the temperature of the muddy contents.

From the descriptions quoted it is evident that there has been a decrease in the power of this mud spring, for it is a constantly agitated spring and not a geyser, since it was seen in 1870. When seen by the Washburn party it was probably new. The fact that trees still alive were crushed under the rim of the crater would seem to prove this, as do also the force and violence described by both Doane and Langford.§ A portion of the mud surrounding it was probably ejected, as they supposed, by eruption, but it occurred, I think, when the volcano first broke out. The mud on the trees, as I have indicated, is probably deposited from the steam; at least we know that it will thus form, and as Doane says in his report,‖ the elevation to which it would have to be carried would have to be very great to account for the lateral distribution of the mud, as the vent is small. The lateral distribution is easily accounted for, if the steam carries it, and the wind blowing from different directions at different times would be sufficient to coat the trees on all sides of the crater. Even when Doane, Washburn, and Langford saw it in 1870,

* Report of U. S. Geol. Surv. of Terr. for 1872, p. 113.
† Reconnaissance of Northwest Wyoming in 1873, by Capt. W. A. Jones, p. 196.
‡ The Great Divide, p. 248.
§ Langford describes the Mud Volcano in Vol. II of Scribner's Magazine, p. 17.
‖ Yellowstone Expedition of 1870, p. 18.

there were no actual mud eruptions, although there may have been one not long before. It was probably in about the same condition as the steamboat vent in the Gibbon Basin was at the time of our visit this year. In the latter case, however, the steam-vent is in the rock and does not pass through a mud bank as is the case with the Giant's Caldron.

Grotto.—There is a cave or grotto-like hole in sandstones and clays at the head of a ravine which is a branch of the one leading from the Giant's Caldron. The opening is 3 feet high, 8 feet wide, and about 20 feet deep. The top of this entrance is somewhat like a gothic arch, and is coated with a thin coating of vivid green vegetation where the steam strikes the rock. The cavern has a slight downward inclination, and at the back of the cave the steam escapes in pulsations of about 1 minute 10 seconds. These pulsations shake the ground, and there is a roaring noise in the cavern. With each pulsation there is a gush of water, which is clear as crystal. The flow from the spring is not very great. In 1871 the temperature was 184°; in 1872, 182°, and in 1878, 181°. This does not necessarily prove a decrease in temperature, as the difference of 3° may be due to a slight difference in the thermometers or to the difference in the place of taking the temperature. The colors over the entrance to the grotto are green and red, and add to the beauty of the spring. The water has a slight alum taste, and gives off a slight odor of sulphuretted hydrogen. This is the only really clear spring at this locality, and it is due to the fact that the water escapes through the sandstones, and escapes from them without coming out into a basin of mud, as do most of the other springs in the surrounding groups. As the accompanying table will show, most of the springs at Mud Volcanoes are either sulphur springs or salses. There are all grades of the latter. A large number are found on the right bank of the river. They are not included in the table. Professor Hayden visited them in 1871, on his way from the lake to the east side of the falls, and describes them as turbid and mud springs. One he called the mud sulphur spring. It has a basin 15 feet by 30 feet, and in it three centers of ebullition. Professor Comstock describes one at this locality as follows:

> One of these [mud bowls], near the water's edge, strongly reminds one of a large kettle of boiling soap; the resemblance to this uninviting substance being increased by the peculiar streaky appearance arising from the imperfect mixture of the yellow sulphurous, the red or pink ferruginous, and the blue and greenish argillaceous ingredients of the mud. The mud-paste is in a constant state of sputtering ebullition, and it is occasionally spurted with force to a height of 2 or 3 feet. There were some signs about the rim of the bowl of recent more vigourus action. There are some springs bubbling from the river near the northern or eastern shore. The springs are of the same general character as those on the left bank and give off sulphureted hydrogen.

The following table presents all the principal springs and salses on the left bank, and compares the temperatures of this year (1878) with those of 1871 and 1872.

The springs are really divided into two groups. Those from No. 1 to No. 12, with Nos. 24 and 25, forming the first, and those from No. 13 to 23 the second.

MUD SPRING AT MUD VOLCANOES 1871.

Springs at Mud Volcanoes, on Yellowstone River, about 6 miles below the lake.

No. or name.	Size.	Temperatures in 1878.	Temperatures of air in 1878 with time of observation.	Temperatures in 1871.	Temperatures in 1872.	Remarks.
		°F.	°F.	°F.	°F.	
Mud Geyser.	Basin, 60 feet diameter in depression which measures 150 by 200 feet, and is 8 feet deep.	127 on the edge with the basin full.		191	125 to 180	
1	3 feet diameter	Not taken		Not taken	190	Two mud springs.
2	10 feet diameter	138 when full of water		179	168	These are in the same basin or depression with the Mud Geyser.
3	10 feet diameter	Not taken on account of water disguising the orifice.			168	
4	6 feet diameter	128		Not taken	126	This is a turbid spring in ravine about 250 yards back of the Mud Geyser.
5	5 by 15 feet			Not taken	156	3,500 feet above Mud Geyser at head of ravine in which No. 4 is situated.
6	75 feet diameter	150		153	134	Turbid, greenish sulphur spring with several centers of ebullition; cannot reach the center.
7	3 feet diameter	Not taken		Not taken	136	Lavender Mud Spring; very thick in 1878.
8	12 by 20 feet	86		Not taken	88	Near No. 6 and 14 feet from No. 7 is a large sulphur pool.
	a 1 by 3 feet	*a* 78				*a* is a lavender mud pot.
	b small hole	*b* 119				*b* is a bubbling hole, of which there are several.
9	20 by 60 feet	132	42° at 9 a. m.	150	140	Large greenish sulphur hole with many centers of ebullition. In ravine with Giant's Caldron.
10	2 feet diameter	Not positively recognized			124	
11	1 by 3 feet				140	
		a 133		185 These occupy on		*a* These are on ravine from Grotto; *b* is sulphur; *a* is simmering spring; *c* mud pot.
		b 50		184 the map of 1871		*b*
				187 place of a, b, and c		
12, Grotto	3 feet high, 8 feet wide, and 20 feet deep.	181		184	182	
13	15 by 30 feet	80 in the pool			94	Greenish sulphur and alum pool with many sizzling holes around it.
14	2 feet diameter	a 116		180	180	
		b 160				
15	20 feet diameter, 10 feet deep				163	Light-colored mud spring.
16	60 by 500 feet	102		170? to 184	92	Large sulphur spring with clear bubbling holes outside. The temperature, 170° of 1871, may have been taken in one of the latter.

Springs at Mud Volcanoes, on Yellowstone River, about 6 miles below the lake—Continued.

No. or name.	Size.	Temperatures in 1878.	Temperatures of air in 1878 with time of observation.	Temperatures in 1871.	Temperatures in 1872.	Remarks.
		°F.	°F.	°F.	°F.	
17	Small holes				148	Close to No. 16.
18	1 inch diameter				172	
19				182	182	Mud spring.
20	6 by 7 feet			Not taken	Not taken	Mud pot.
21	30 feet diameter			163		Boiling mud pot.
21½				175		Mud hole near No. 21.
22		106		143		Turbid sulphur pool below No. 21.
23		*a* 182				In ravine above or south of the springs enumerated from 13 to 22. There is a steam-vent at head of ravine.
		b 179				
		c 177				
		d 166				
24	Triangular, 6 feet on the sides	187	48½ at 1.47 p. m.	Not taken	Not taken	Ravine above that of No. 23 on the river's bank. *a* and *b* are on line of fissure back from No. 24; *c* is detached. Water is milky-hued.
		a 171				
		b 173				
		c 186				
25						Old mud spring.

The three principal springs of this locality having been described, I now present the special points in reference to the others that are enumerated in the table:

No. 1.—This mud spring has a funnel-shaped crater, at the bottom of which the mud rises in two hemispherical masses, which every now and then burst, sending up a spurt of mud. The contents do not appear as thick as in 1872, due probably to the rainy season supplying a greater quantity of water. Near the principal crater is a second of the same shape, with quiet muddy water at the bottom.

Nos. 2 and 3 are in the basin of the mud geyser, which was so filled with water that the outlines of these springs could not be distinguished, and the temperatures were therefore not taken.

No. 4 is a turbid mud spring, with a scum on the surface. It gives off sulphureted hydrogen.

No. 5 is a mud pot, which appears to be almost dried up, although boiling and throbbing can be heard somewhere below.

No. 6.—In this spring the green color is probably due to the color of the basin or bowl of the spring.

No. 8.—Besides the springs enumerated in the table, there are other simmering holes, and opposite them across the trail is a steam sulphur vent.

No. 9.—Above this on the edge are numerous small springs.

No. 11 *a*, *b*, and *c*.—Above these the ground on the edge of the small rivulet is perforated with sulphur-lined steam vents and sizzling holes.

Nos. 13 and 14.—These springs occupy one basin, No. 13 being an irregular pool of green sulphur-water, outside of which are a number of sizzling holes and several small springs, from 1 foot to 2 feet in diameter. Under No. 14 two of these are given. They are constantly boiling, and are really sources of supply to the pool (No. 13). The small water-ways leading to the latter are lined with a vividly green deposit.

No. 15.—The contents of this mud pot is a light-colored mud that looks like paint. At one end there are hemispherical bulges. Back of the mud crater there are sulphur-lined vents on the side of the hill. There are also other mud craters near by.

No. 16.—There is a very large sulphur pool, with vents and springs on the hill back of it. Nos. 17 and 18 are two of these holes near the large pool. No. 19 is a small mud volcano near it. North of it is a blue mud pot or volcano, with a circular mound around it. At the bottom is a blue mud, so thick that the steam which escapes from a great many points throws it into concentric rings. Hemispherical bulges also occur and burst, splashing the mud in all directions. Steam is constantly escaping, and the hole looks like some great pot of blue or lead-colored paint.

No. 20.—This is a mud pot with lavender-colored contents. It is at the head of a ravine leading down to Nos. 21 and 22, and has a basin 6 by 7 feet, in which are 7 or 8 points of bulging hemispherical masses 6 inches in diameter; are raised 3 or 4 inches, and leave the mud in rings that look like melted taffy. This spring was not seen in 1872 or 1873, as it is some distance back of the others.

No. 21 is a large, constantly boiling mud pot, with greasy-looking contents.

No. 22 is a turbid sulphur spring or pool, with yellowish water, which has many points of ebullition. The temperature appears to have declined since 1871.

No. 23.—This number designates the springs in a ravine near the river's edge, just south of the springs included in the group from No. 13

to No. 22. They are at the foot of a bluff of rock that rises from the river's bank. The temperatures are from 166° F. to 182°. At the head of the ravine a little farther south there is a steam vent. On the east side of the river, immediately opposite this locality, there are springs on a bar in the river, and steam vents and a mud spring on the bluffy point.

No. 24 designates the next ravine to the south of No. 23, and is the one that brings overflow from Grotto and Grant's Caldron whenever there is any to bring. The springs are on the river edge, and consist of openings in a conglomeritic sandstone, in which the water has a milky hue. There are also several small mud pots. No. 24 is the principal spring, and comes out from a small grotto-like cavity in the rock, which is lined with a green, red, and yellow coating, probably organic in character. Below the spring is a fissure about 4 feet long and 2 to 3 feet wide; *a* and *b* are openings in this, and are evidently only on the line of waterway from the main spring, which accounts for their lowered temperature; *c* is a fissure in a fine-grained sandstone, which appears to underlie the coarser rock in which No. 24 is located. It is about 3 feet long and gives off but little water. The rocks surrounding these springs are tinged with iron. Back of 24 are steam holes, and in the river there are places of bubbling. These springs are about 40 feet below the level of No. 9, and although small, have in the two that are really springs (*a* and *c*) the highest temperatures at the locality, with the exception of the mud geyser.

No. 25.—Following up the ravine which leads from the mud geyser and passing Nos. 4 and 5, we soon come out on a sort of plateau, and turning to the left find a flat place that was once the seat of mud springs. Only one at the present time is active.

VIOLET CREEK SPRINGS.

These springs were not visited by us in 1878, and I therefore quote from my report of 1872 (pages 134 to 136), where they are first described. Violet Creek is laid down on the accompanying map of the Park as a branch of Alum Creek, near the sources. In my notes of 1872 I mention the first group of springs as being about 5 miles northwest of camp (at Mud Volcanoes), whereas those laid down in the map are at least 10 miles distant. The latter are without doubt either the group described by Professor Comstock as "boiling springs near source of Warm Spring Creek"* or are included under his Prairie Group.* Five miles from our camp would bring us to the sources of the creek into which the drainage from Crater Hills flows, and this is what I understood at the time to be Alum Creek. Violet Creek is therefore a branch of this stream. One of the groups described in my report may be included under Professor Comstock's Prairie Group, the description of which I shall quote further on. We had no map with us, and during the season of 1878 I had not the time to revisit the groups, so as to identify them on the later map. I shall therefore simply quote the descriptions given in the report for 1872, and add afterwards Professor Comstock's descriptions, in a somewhat condensed form, under the headings given in his report.

The first spring we met with was on the right bank of the creek, in a siliceous cone-like mound that rises six feet above the bed of the stream. Its temperature was 126° F., the air being at 70° F. The bed of the creek was filled with confervoidea, leading us to suspect that there were springs still farther up. After a further ride of

*Report of Reconnaissance of Northwestern Wyoming, p. 216, 217.

FIG. 4.—Chart of Springs at Mud Volcanoes, 1871.

about a quarter of a mile we came to quite a large group of hot springs, lining both sides of the creek. The first spring I will describe is on the right bank of the creek, in the center of a white mound 20 feet in diameter and rising 10 feet above the bed of the creek. This mound is formed of deposits from the water, which consist mainly of various carbonates and silica. The orifice of the spring is circular and about three inches in diameter, and looks as though it had been artificially punched in the deposit, so mathematically exact is it. The water gives off carbonic-acid gas, leaving a deposit of iron. Its temperature was 190° F., the air being 70° F. Spring No. 2 is on the opposite side of the creek, and has a basin measuring 4 feet by 2 feet; the temperature of the water was 160° F., the air remaining at 70° F. No. 3 has a circular basin 2 feet in diameter, which is lined with an abundant deposit of iron. Carbonic-acid gas bubbles through the water. It temperature was 158° F. No. 4 is 6 feet deep and 1 foot by 3 feet in diameter, and has a temperature of 188° F. The next three springs had temperatures as follows: No. 5, 192° F.; No. 6, 194° F.; and No. 7, 188° F.; the air still remaining at 70° F. All these springs have circular orifices of about 6 inches diameter, and the water proceeding from them flows over a series of small terraces, resembling those of the Gardiner's River springs on a miniature scale. These basins are lined with a gelatinous form of silica, which has a leathery appearance and is coated with an iron deposit. The springs are about 10 feet above the level of the creek, and all give off carbonic-acid gas. No. 8 is very irregular in shape and almost hid in the grass, about 40 feet from the creek. There is a slight bubbling in it, and its temperature was 178° F. No. 9 is a small spring, 2 feet in diameter and 1 foot deep, lined with confervoidea, and having a temperature of 140° F. No. 10 is a very pretty spring, about 4 feet above the creek, and has a beautiful scalloped edge, moss-lined on one side. Its temperature was 175° F. The boiling point at this locality is 198°.3 F. None of the springs reached this temperature, 194° F. being the nearest approach. The rocks exposed near these springs are sedimentary and contain a great deal of obsidian.

About three-fourths of a mile farther up stream we came to the head of the creek, and found that it originated in a most important group of springs. [This group may be on the main Alum Creek, but I am not now certain.] They are situated in a semicircular basin, bounded by a low hill, wooded on the summit. The sides of the hill are perfectly bare and covered with a glaring white deposit, through which steam jets force their way. Looking down into the basin from the top of the hill is like looking into a volcanic crater. The fumaroles, solfataras, and mud springs scattered through it give it a most peculiar appearance. The general color throughout the basin is a glaring white, relieved here and there by patches of brick-red iron deposits and the yellow of sulphur masses that are scattered throughout the basin. The crust extending over the basin is lined with beautiful crystals of sulphur. On the left of this basin there is a ravine, covered with deposits of the same character, but containing no springs. There are a few fumaroles remaining, the evidence that once the ravine was the site of active springs. A few yards on the opposite side of the basin there is a second ravine, similar to the first, and in which also the springs are all dead, nothing remaining but the rust-colored deposits. I will give the different springs in this basin below in tabular form:

Springs at the head of Violet Creek.

August 10, 1872; time of observation, 12.30 a. m.; general elevation above sea-level, 8,059 feet; boiling point, 198°.1 F.

No.	Character of spring.	Size.	Gas evolved.	Temperature of spring.	Temperature of air.
1	Siliceous	8 by 10 feet	Steam	185° F.	72° F.
2	do	3 feet diameter	do	172	72
3	do	2 feet diameter	do	194	72
4	do		do	194	72
5	Sulphur	20 feet diameter	Steam and sulphureted hydrogen.	Not taken.	72
6	do	30 feet diameter	do	165	72
7	Mud spring	2 by 4 feet	do	170	72
8	Sulphur	8 feet diameter	do	140	72
9	Blue-mud spring	6 by 10 feet	do	162	72
10	White-mud spring	1 by 3 feet	do	168	72
11	Blue-mud spring	3 feet long	do	188	72
12	Yellow-mud spring	4 feet diameter	do	180	72
13	Blue-mud spring	2 inches diameter	do	190	72

Besides the springs enumerated in the table, there were many smaller ones, and a few large pools, through which the gases bubbled at various points. The ground near the majority of them was too treacherous to allow of our approach. There are also a great many steam vents lined with sulphur crystals. The hardened deposit about

some of the mud springs is an indurated clay that has been deposited by the springs. The first four springs given in the table have clear water, and the first one was in violent ebullition, the water at times rising 4 feet above the ordinary surface. In No. 10 I found butterflies that had fallen into the water and been killed by the heat. The odor of sulphureted hydrogen was not so strong at this locality as at the foot of Mount Washburn.

On the way back to camp we came across another group of springs, about a mile southeast of the group given above, and having an elevation about 200 feet lower. They are situated in a ravine bordering a small branch of Violet Creek. The following table will show them all at a glance:

Springs on branch of Violet Creek.

August 10, 1872; time, 2 p. m.; elevation above sea, 7,873 feet; boiling point, 198°.5 F.

No.	Size.	Gas evolved.	Temperature of air.	Temperature of spring.
1	3 by 4 feet	Carbonic acid and steam	68° F.	160° F.
2	10 feet diameter	do	68	184
3	5 feet diameter	do	68	154
4	5 by 2 feet	do	68	188
5	3 feet diameter	do	68	180
6	5 by 3 feet	do	68	191
7	7 by 3 feet	do	68	186
8	3 feet diameter	do	68	192
9	8 by 1 feet	do	68	194

The amount of carbonic acid given off from these springs is small, and although there is considerable bubbling in some of the springs, it is caused mostly by the escape of steam. This in some is enough to cause the ground to tremble beneath. All the springs deposit iron. The first three springs given in the table are on the edge of a pool of water having a diameter of 100 feet by 50 feet, in which the thermometer stood at 120° F. There is also one spring in the midst of this pool which was beyond reach. The bottom of the pool is lined with gelatinous silica, which is coated with oxide of iron. The edge of the pool next the creek slopes to the level of the stream in a series of small basins, over which the water flows. The creek itself is divided into a number of basins formed of the deposits (mostly carbonates(?)), and the water flows from one basin to the other, they being at different levels. These basins are filled with a luxuriant growth of very bright confervoidea. The temperature of the water in the creek a short distance below the springs is 140° F.

WARM SPRING CREEK OR PRAIRIE GROUP.*

These springs are described by Professor Comstock, who passed them on his way to the Geyser Basins of the Fire Hole. His trail led up Alum Creek (Warm Spring Creek on his map). He says:

The first collection of hot springs occurs about two miles above the mouth of the creek. They are situated mostly upon the left bank, not far from the main stream, with which they are connected by a small branch entirely supplied by their overflow. The temperature of the water is sufficiently high to heat the contents of the creek to a very perceptible amount above the previous temperature, and to make this influence felt for some distance below. The springs themselves do not differ essentially from others which have already been described not far distant; but such differences as were noted furnish a clew to the causes of observed dissimilarities in the members of a single group. In other words, we are here given a striking illustration of the principal elsewhere enunciated, that variations in the character of different springs are dependent not only upon dissimilar geological structure but also very largely upon variation in the intensity of the subterranean forces. The structure at this point is almost identical with that along the banks of the Yellowstone in the neighborhood of the Salses; but the deposition of sulphur is here more abundant in proportion to the size of the springs. In general the bowls may be described as sputtering fumaroles, though there are a few fair-sized pools from which little or no vapor escapes. The clearness of the water, compared with that usually present in springs emerging from the old lake deposits, and the marked absence of mud bowls, is a matter of some surprise to one who has previously visited the groups which lie in similar relations to the lacustrine form-

*See report of Prof. Theo. B. Comstock in Report of Reconnaissance of Northwestern Wyoming, p. 216.

ation. This seeming discrepancy may readily be understood, however, by referring it to the comparative feebleness with which the water is ejected in most of the members of the Prairie Group.

Professor Comstock also says that iron is less abundant, which want he refers to the constant and rapid flow of water observed in the group. He also says:

The small amount of special deposits formed by precipitation from the water after it has become condensed by cooling points to the conclusion that the solution of the subterranean rocks is less complete than in many localities.

It has been my experience that the waters of the springs of these regions, with the exception of the sulphur springs, do not precipitate much, if any, deposit upon cooling, but that the formation of deposits is due almost entirely to the evaporation of the water, and that the character of the deposits varies according to the circumstances under which the water evaporates.

Another important collection of thermal springs occurs two or three miles farther up the valley of Warm Spring [Alum] Creek. These were just in view from the point at which we turned southward away from the creek. * * * The water which flows from them remains quite hot until it has reached a point below our crossing. * * * So far as we were able to ascertain, the prominent springs of this upper group emerge from the volcanic rock. Quantities of vapor were ascending from the locality at the time of our passing.

If the distances given by Professor Comstock are correct, it would indicate that the springs last mentioned are the ones marked "Violet Springs" on the map of the Park in this volume, which I think on this point incorrect.

BOILING SPRINGS NEAR SOURCE OF WARM SPRING CREEK.*

The springs described by Professor Comstock under this head are, judging from the maps accompanying his report, about a mile or a mile and a half east of the Hot Sulphur Springs indicated on the map of the Park. The latter, as will be noted further on, give off considerable sulphureted hydrogen, which this group, as indicated by Professor Comstock and Dr. C. L. Heizman, does not to any great extent, and have deposits that are mainly siliceous. The locality is indicated as follows by Professor Comstock:

After crossing Warm Spring [Alum] Creek [near Violet Springs?] we pushed on in a southwesterly course for several miles. * * * After a time we were able to proceed, when we soon struck a trail (Barlow's, 1871) for which we had been searching, which led us near to the source of the creek. By leaving the trail at a point where it turns to make a considerable detour, we made an advantageous cut-off, not impracticable for riding animals, and quickly reached an interesting group of springs, in the neighborhood of which we spent the night.

The following descriptions are copied from Professor Comstock's report:

The stream on which these hot springs are situated probably comes from cold springs some distance above, a number of which also add to its volume from along its sides in a meadow above our camp. Here it also meets with a number of hot springs, which, with the contributions from the numerous boiling springs below, soon render the water excessively hot.

The springs are scattered along both sides of the creek above and below, but the most powerful and interesting bowls occur near the edge of the current, on the left bank, just within the lower end of the short pass, or gorge. This set of jets, as they have been called, is the nearest approach to geysers that we have yet noticed, and, in the ordinary acceptation of the term, it would not be improper to designate them thus, but it will be more convenient and, for our purpose, more correct to describe them under the present head. * * * These springs vary in size and intensity from

* Report of Reconnaissance of Northwestern Wyoming, p. 217.

furious boiling pools, in which the water spurts but an inch or two, to those in which it is thrown to a height of more than twice that number of feet. One bowl in particular, the largest in the group, is partly surrounded by a chimney nearly 5 feet in height, and the water is occasionally thrown to a height of more than 6 feet, so as to pass completely over this rim. The contents of this bowl are continually agitated, and the constant but irregular thud of the successive impulses reminds one vividly of the sound produced by the dashing of the water on a rock-bound coast. The chimney is open on the side next the stream, thus allowing the overflow to pass off freely in this direction. * * * There are several smaller orifices, with correspondingly diminished chimneys, but the majority of the minor springs of this group are mere bubbling jets, in which the water is occasionally spurted to the height of a few inches, and these are not usually provided with raised walls. In all of these, however, there is something of an approach to the same structure, and a few differ only in degree from the largest bowl.

Sulphureted hydrogen is evolved from some of these springs, and small deposits of sulphur are found in favorable situations, but the chief and most characteristic ingredient throughout is silica, of which the chimneys are mainly composed.

Were we to classify these jets according to the character of the deposits alone, their place would undoubtedly be among the geysers, for we find here not only a composition nearly identical with that of the products in the Fire Hole basins, but even the peculiar structure of the geyser products is very closely imitated in the formations about the bowls. About some of the smaller jets clear white deposits of the most beautiful geyserite are formed, resembling porcelain beneath, with an upper surface of delicate tracery, or of coarser excrescency, according to the force of the falling water. Sometimes a glistening pink surface is disclosed by the fracture of the rougher incrustations, which are usually of a light-brown color. Manganese in the form of pyrolusite (manganic dioxide) is extremely abundant as a coating to parts washed by the outflow and by the falling spray, as well as on portions of the interior walls of many of the bowls. Iron is not scarce, being more particularly present exteriorly, where it gives rise to the brown and pink colors which are visible in the siliceous crust, and it is noticeable that the growth of green cryptogamic vegetation in the water is especially abundant in those spots where iron is most common as a deposit.

This group of springs was first described by Captain Barlow, who met with them on his trip from the Yellowstone River to the Geyser Basins. He says:*

Ten miles west of the river we came upon a very hot stream, formed from the overflow of a large system of springs, in some respects more interesting than any we had yet encountered. One, with a curious crater, was constantly throwing up boiling water to the height of several feet. The crater is of calcareous [siliceous?] rock, 6 feet in diameter, and bears a strong resemblance to a human ear. A beautiful branch joins this stream from the northwest, cool and highly impregnated with alum. The water from these springs is remarkably clear and colorless, except that from a single one, which had the bright color of gamboge. On both sides of the hot stream the ground is a soft, hot marsh, very dangerous to examine, and it is only in the immediate vicinity of the largest springs, where a rocky deposit has been formed, that one is entirely safe. A steam jet, flowing beneath the surface of the water into the stream, at one point presented a very interesting appearance, and gave off a very novel sound, something like that made by the spindle of a spinning-machine.

The spring with the crater is the one described by Professor Comstock. Captain Barlow is the discoverer of the group. We passed to the westward of them in 1871 and south of them in 1878, so that I have never seen the group, which is especially interesting from the occurrence of manganese in its deposits.

Dr. C. L. Heizmann, in his report on the mineral and thermal waters, speaks as follows of the springs on Alum Creek:†

All along its banks were hundreds of boiling and bubbling springs and remains of extinct ones, all of which may be classed with the last [*i. e.* mud volcanoes and turbid lake springs], although there is a greater profusion of clear alum springs, evolving only sulphureted hydrogen, intermixed with the others, than elsewhere. One, near the head of the stream, was for the most part walled (6 feet high) by its deposit on small timber, which, partially silicified, gave it the shape of a yellowish-brown, snaggy cone. Although not exactly like a geyser, it nevertheless threw constantly

*Reconnaissance of the Yellowstone River, Senate Ex. Doc. No. 66, 42d Congress, 2d session, p. 19.

†Report of Reconnaissance of Northwestern Wyoming, 1873, 1875, by Capt. W. A. Jones, p. 302.

its water (194°) with great violence against its sides and 8 feet into the air. It contained lime, iron, alumina, magnesia, sulphides, sulphates, and chlorides, and evolved sulphureted hydrogen but no carbonic acid. All of the springs surrounding it, very numerous and close together, evolved carbonic-acid gas, but, strangely, some of them only it and sulphureted hydrogen.

The creek above, besides being supplied by many small springs (100°–180°) on its banks, contains in its bed many bubbling carbonic acid gas, but no sulphureted hydrogen.

The temperature of the running water here was 84°. However, a tread or the mere piercing with a stick of its sandy bottom anywhere within one-half mile started a thin, hot, and unbearable stream, containing carbonic acid gas, but no sulphureted hydrogen. Of course, as its flow was only momentary, its relative temperature could not be got, but the temperature of the surface sand, where no visible spring existed, was the same as that of the water, 84°. Above the point where the camp was made, and where this phenomenon gradually disappeared, the water of the creek was pure and potable.

HOT SULPHUR SPRINGS, OR BRIMSTONE GROUP.

This is a collection of fumaroles and solfataras at the head of Alum (Warm Spring) Creek, near the divide between the East Fork of Fire Hole River and the Yellowstone drainage. On the map of the Park it is indicated as Hot Sulphur Springs, and Professor Comstock, in his report, names it "Brimstone Group." It is south of the Boiling Springs Group, and was passed by our party in 1871, and is mentioned in my report for that year.* Captain Barlow also passed them after leaving the Boiling Hot Springs already described. The Howard wagon road passes the springs, or rather fumaroles, for the latter predominate. Dr. Hayden thus describes this locality:†

There was one locality, where the deposit covered several acres, that presented a most attractive picture. The entire area was thickly covered with conical mounds of various sizes, ranging in diameter from a few inches to a hundred feet or more, and these cones, or hillocks were full of orifices, from which steam was issuing. All these little chimneys, or orifices, were lined with the most brilliant crystals of sulphur, and when the heated crust was removed we found the under side adorned in the same manner. The basis of the deposit was silica, as white as snow, but it was variegated with every shade of yellow from sulphur, and with scarlet or rose color from oxide of iron. In the distant view the appearance of the whole country may be not inaptly compared to a vast limekiln in full operation.

Captain Barlow, describing this area, says:‡

Then we came upon an immense area covered with sulphur vents, each hillside containing thousands of these little crystal chambers, which, upon being broken into, sent forth quantities of sulphuric steam. In passing through the orifice from below, this vapor had been sublimated into beautiful crystals of pure sulphur, varying in dimensions from the size of a needle to the thickness of the finger, while some were even larger. The country presents the appearance of a vast limekiln in active combustion. The crust of soft white rock was exceedingly thin, requiring great caution in picking a route for the animals.

Professor Comstock, speaking of these springs, says.§

The time spent in this locality was not sufficient to allow of much careful work, and the nature of all the products was, consequently, not ascertained. Sulphur, however, is the principal ingredient, being probably produced here in greater quantity than in any other portion of the National Park thus far described by the several authorities. There are some bowls of considerable size, but the most striking feature of the whole area is the occurrence of a large number of small orifices, in which the water bubbles constantly, giving rise to deposits of crystallized sulphur, which are formed upon the walls of numerous cavernous incrustations.

There are really two groups of springs, from one of which quite a large stream of water passes. There are a number of sulphurous ponds

* Report United States Geological Survey for 1871, 1872, p. 182.
† *Ibid*, p. 102.
‡ Reconnaissance of the Yellowstone River, Senate Ex. Doc. No. 66, Forty-second Congress, second session, p. 19.
§ Report of Reconnaissance of Northwestern Wyoming, p. 221.

also, and what most distinguishes these springs is the presence of calcareous matter in the deposits, which is the result of the water passing through limestone. The sulphur vents, however, are located on trachyte, on which are probably remnants of lake deposits. In this region it is somewhat difficult to tell at times what is the direction of the drainage, as the timber is heavy and a number of depressions exist which appear to have no outlet.

Recapitulation of Hayden's Valley Springs.

Name of groups.	Number of springs.	Highest temperature.
		°F.
Forest Group	20+	190
Crater Hills Springs	56+	197
Mud Volcano Springs	30+	191
Violet Creek Springs	22+	194
Prairie Group (or Warm Spring Creek Springs)		
Boiling Springs, near source of Warm Spring Creek		194
Brimstone Group		
Total springs	128+	

The only genuine geyser described in this chapter is the "Mud Geyser" of Mud Volcanoes, unless the Caldron near it should turn out to be one. The geysers described by Comstock in the Boiling Springs are probably small, and might be classed as pseudo-geysers, although one of them, he says, throws the water to a height of 8 feet.

CHAPTER IV.

SPRINGS OF YELLOWSTONE LAKE.

Yellowstone Lake is the largest body of water within the Park, and its shape has often been compared to that of an outstretched hand, of which the thumb and index and little fingers are swollen and deformed, and the other two fingers dwarfed. Of the arms representing the latter, one in dry seasons becomes a separate lake, which has been named Delusion Lake. The greatest length of Yellowstone Lake from north to south is 20 miles, and the width from the eastern shore to the west side of the west arm a little over 14 miles. The main body measures about 7 by 12 miles. Its greatest depth is 300 feet.

On early maps of this region a lake is indicated as the head of the Yellowstone River, in about the position of Yellowstone Lake, but with the shape anything but correctly shown. On some of these maps it is called Eustis's Lake and on others Sublette's Lake.* On later maps it appears as Yellowstone Lake, and is so named on the the map accompanying the report of Captain Raynolds's expedition of 1859–'60.

*An examination of the maps illustrating vol. xi of the reports of surveys for the Pacific Railroad shows that on the maps as known in 1795 the Yellowstone River is not even indicated. A sketch made in 1818 has Eustis's Lake, but the shape is incorrect. This map was published by General Land Office. On Finly's map of 1826, no lake is shown, nor is it indicated on Bonneville's map of 1837.

In the report of the survey for 1872 Professor Bradley says:

The first map which, so far as known, represents the lake with anything like its true form is a manuscript one by Jedediah S. Smith, who hunted through the mountains from California to the British Possessions during the years from 1821 to 1830. The original was purchased in Oregon for the War Department, but is supposed to have never reached Washington. A copy taken in 1853 exists in the hands of Mr. George Gibbs, of New Haven, Conn.

The present lake is the remnant of one that formerly extended over a much larger area, and which had a more regular shape, the arms to the southeast being then merged in the main body. One extension also occupied what is now called Hayden's Valley.

The water of the lake is always cold, averaging about 60° F., and has frequently quite a strong surf dashing on its beach, a strong westerly wind usually ruffling its surface in the afternoons. The surrounding rocks are mainly volcanic, rhyolites predominating. On the immediate confines of the lake the lacustrine formations deposited by the old lake are found.

On the west, southwest, and south the country is plateau-like, and the divide or watershed between Yellowstone Lake and the Shoshone Lake is only 300 feet above the level of the former. On the east is the Yellowstone Range, whose peaks rise from 2,000 to 3,500 feet above the lake. This range, with the mountains southeast of the lake, form the impassable (?) barrier that prevented Boneville in 1833 and Raynolds in 1860 from reaching the lake. It can, however, be crossed in two places at least, as was proved by Captain Jones's expedition of 1873, viz, from the head of Wind River to the Upper Yellowstone River, and from the head of the Stinking-Water River to the head of Pelican Creek. The springs on the margin of the lake are comparatively inactive, those of the west being the most important.

SULPHUR HILLS.

This name has been somewhat inappropriately given to a mass of old spring deposits on the north side of the lake, which are made up mainly of silicious materials, although sulphur is present in small quantity. I have never visited the hills, and therefore present the descriptions of those who have visited them. Dr. Hayden, in 1871, writes of the locality as follows:

Sulphur Hills, on the north side of the lake, is another of the magnificent ruins, of which only a few steam vents now remain. The deposit, however, is a large one, and covers the side of the mountain for an elevation of 600 feet along the lake shore, the huge white mass of silica covering an area of about half a mile square, and can be seen from any position on the lake shore, and appears in the distance like a huge bank of snow.

The great mass of hot-spring material built up here cannot be less than 400 feet in thickness. A large portion of it is pudding-stone and conglomerate. Some of the rounded masses inclosed in the fine, white silicious current are themselves pure white silica, and are 8 inches in diameter. It is plain, from the evidence still remaining, that this old ruin has been the theater of tremendous geyser action at some period not very remote; that the steam vents, which are very numerous, are only the dying stages. These vents or chimneys are most richly adorned with brilliant yellow sulphur, sometimes a hard amorphous coating, and sometimes in delicate crystals, that vanish like frostwork at the touch. It seems that it is during the last stages of these springs that they adorn themselves with their brilliant and vivid colors.*

Professor Comstock, writing of this locality, says:

At this point there are three deep basins or hollows between ridges of the old spring deposits, in each of which there is a small group of springs. From the west

*Report U. S. Geol. Surv. of the Terr. for 1871, 1872, p. 136.

side a powerful stream has issued at one time, draining off the surplus water by a series of interesting cascades. Throughout the whole section between this spot and Green Spring [on Pelican Creek] there has been, during a recent geological period, and probably within the historical epoch, a degree of activity greater than is at present manifested anywhere in this vicinity; and yet it does not appear that the existing phenomena are materially less than they have been for very many years * * * The history of the accumulation of the extensive deposits, here forming a mass several square miles in area and fully 200 feet in thickness, is not to be read in an hour, but it will require the patient labor of years to unravel the intricate problems which arise even while viewing hastily a single section like this, which is but one of the lesser of a hundred of this nature * * * The snow-white aspect of the hills, which enables them to be distinguished from a great distance, is due to the silica which forms the great bulk of the deposit. Sulphur exists in broken masses, mostly amorphous, with some sublimated crystals about the active springs. Occasional brick-red spots are visible, caused by the presence of iron. The mass of the silicious deposit is a fairly compacted white rock, fine grained, and much jointed; but there is much of a very beautiful tough quartzite, with a conchoidal fracture, and having a pearly luster, or it is sometimes iridescent in a favorable light.

Between 12 m. and 1 p. m. of the 4th of August a heavy cloud of vapor was observed ascending from this spot while passing along our main trail, one mile distant. I visited the locality about 2 o'clock in the afternoon of August 7, and also had several other good opportunities of observing such emission, if it had occurred, but not near midday. Had I not seen it I could not have believed it possible for such a quantity to be emitted by such a small number of apparently unimportant springs as were afterward found to occupy this section. Judging from this accidental circumstance, it may not be unfair to suppose that these fumeroles are periodically agitated, though nothing can be predicated concerning the regularity of the action, nor the duration of the quiescent intervals.*

TURBID LAKE GROUP.

Turbid Lake is a small, heart-shaped body of water, about a half mile long by a quarter of a mile in width, and was named from the muddiness of its water, through which sulphurous gases bubble constantly It is back of Steamboat Point, about 2 miles from the lake. Two small streams flow into it, and the region bordering the lake, near the entrance of the one from the east, is the seat of quite a number of important springs. These were first visited in 1871, while we were in camp at Steamboat Point.

The lake is 400 or 500 feet above the level of Yellowstone Lake, and has a temperature of 60° or 65°. It tastes strongly of alum.

On the south side of the mouth of the creek from the east the principal springs are located. They are of all sizes and descriptions; some have raised vents and others are turbid springs. The surface is perforated like a colander, with simmering vents from a few inches in diameter to several feet. The temperatures here were as follows: Sulphur Mud Spring, 178° F.; White Turbid Spring, 190° F.; Turbid Springs, 176° F., 190° F., 182° F., 176° F., and 190° F. Back of these the side of the hill was composed of sulphur, alum, and clay deposits, which made unsafe footing, a step being apt to cause a new spring to burst forth. In the bed of the creek, east of these springs just described, is the most powerful spring in the group. It is 10 feet wide and 2 feet deep, and boils up furiously. Although the water is milky, the temperature is not greater than in the creek above and below the spring. Farther down the creek, below the sulphur vents and mud springs, were two more, close to the stream, having a temperature of 186° F. On the north side of the creek are several muddy springs. One of these is black (sulphide of iron?) and the other white. Sulphur is abundant in the deposits near them. The black spring is about 30 feet in diameter, and the muddy water has a strong alum taste.

* Report of Reconnaissance of Northwestern Wyoming, by Capt. W. A. Jones, in 1873, pp. 194, 195.

Farther north, near the shore of the lake, are several cold springs containing common salt, which our riding-animals immediately recognized. From the numerous game-tracks about these springs, it is evident that the place is used as a lick by deer and elk.

Professor Comstock in 1873 visited the Turbid Lake Springs three times, and records the following in regard to periodicity of action in these springs:

About 3 p. m. of the 2d day of August I first caught sight of Turbid Lake, from a high point north of the Stinking Water Pass, 2,000 feet above the level of the springs. At that time no vapor was rising from this spot, although the locality of the concealed Steamboat Springs, which emit much less vapor at any time than the Turbid Lake group when in action, could be plainly discerned by the vapor. On the following day, as previously stated, I reached this locality, at 11 a. m., and discovered that an eruption had occurred before my arrival. Upon the way, at least two hours before reaching the place, I clearly distinguished volumes of white vapor issuing from the direction of the group, and then the view was obstructed by timber for the remainder of the distance. On the 4th of August I found the springs in action at 8.45 a. m., and the emission of vapor had almost ceased at 10 a. m.

Returning to spend the night in this vicinity on the 6th of the same month, no notable quantity of vapor was visible, but during the night a heavy mist shut out the springs from view. When this had been dissipated by the sun, I again saw the springs in vigorous action, before 6 a. m. From these observations it seems reasonable to conclude that the increase of activity, or the eruptive throe, takes place in all the springs of this group quite regularly, beginning before 6 a. m. each day, and continuing for at least four hours, without interruption. It is possible that another period of activity may occur at night; but this I regard as exceedingly doubtful, for good reasons, which it will be impossible to give here.*

My visits in 1871 were both in the afternoon, which is probably the reason I saw no evidence of special activity. The deposits about Turbid Lake consist largely of clay beds, which is the source of the alumina in the springs, and the cause of their assuming the character of mud and turbid springs.

Sulphureted hydrogen is the gas evolved from the springs, and sulphur and alumina the principal constituents of the deposits.

STEAMBOAT SPRINGS AT STEAMY OR STEAMBOAT POINT.

Steamboat Point, or Steamy Point, as it is sometimes called, was so named from the existence on the point of the bluff which here extends into the lake of a powerful steam vent from which a vast column of steam escapes with a continuous roar that exactly resembles the escape from a huge steamboat. The locality is interesting, as it shows the remains of what was once a very active group, the point once having been covered with very active springs. There are at present only two or three very small springs containing any water. One of these is like a sieve through the bottom of which the water bubbles with a simmering sound. There are a number of steam holes, and the ground is perforated in many places, so that one has to be careful in walking over it.

Steamboat Spring.—This is an orifice in solid rock, from which the steam escapes with a constant puffing noise like the escape of steam from a high-pressure engine. The resemblance to the escape of steam from a steamboat is perfect. The second steam jet was named in 1873 by Professor Comstock, who named it the—

Locomotive Spring.—Professor Comstock describes this spring as follows:

A few rods further up the lake [from the Steamboat] sulphurous vapor issues from a cavern, in conglomerate, with a seething noise, as it comes in contact with the waves,

*Report of Reconnaissance of N. W. Wyoming, &c., p. 191.

not unlike the sound produced by the escape of steam from the cylinders of a locomotive moving slowly. For purposes of distinction this will here be called the Locomotive Spring.*

There are besides a number of other steam vents, but the two described are the principal ones and are typical of the others.

Professor Comstock is of the opinion that the action of the waves on the point is gradually converting the Steamboat and other springs into Locomotive Springs, and the latter into boiling springs in the lake, where there are already several. Steamboat Point probably once extended out into the lake as far as Pelican's Roost, which is now an island about half a mile from the present point. The lake has probably worn away the intervening portion, which it might do readily, as the deposits which form the point are soft and friable. Several hundred yards back of the point, on the south side, there is a small group of mud springs, in which the mud is of a pure white color. Dr. Heizmann, in 1873, took temperatures at Steamy Point, and writes:

Steamy Point, covered with large vegetable growth, contained a small number of springs (184°–192°), all bubbling violently, and a few holes in the side of a rocky bank, from which issued jets of steam, but little water, depositing a yellowish brown on the surface. At times, irregularly, the puffing steam was more violent than at others. The ground about these was insecure, as about the mud springs.†

He gives the temperature of another spring as 192°.

The principal constituents of the deposits at Steamboat Point are sulphur, silica, iron, and alumina, and sulphureted hydrogen is the principal gas, although it is not so abundant as at Turbid Lake. Professor Comstock mentions carbonic acid as having been given off from the dried mud from one of the springs when treated with chlorhydric acid, but it was not present in great quantity.‡

MARY'S BAY GROUP.

By this name I have designated the group situated on the northeast side of Mary's Bay, about 2 miles beyond Steamboat Point. The first spring met with on the way from the point toward Pelican Creek is a turbid spring, at the end of a small lake-like pool. It had a temperature of 183° F. A short distance beyond are three boiling springs, with temperatures of 185° F. to 186° F. Near there is a second small pool, with several springs at the north end, having temperatures of 178° F. One of them is a black, boiling spring. Beyond these, near the lake shore, are two springs, one a turbid boiling spring, with a temperature of 180° F. North of these two is a white sand spring, the temperature of which is also 180° F.

These springs were visited in 1873 by Dr. Heizmann, who writes of them as follows:

Between the mouth of Pelican Creek and Steamy Point, on the shore of the lake, is a chain of springs (100°–192°), some steaming, most of them with lead-colored deposit and water, all bubbling carbolic acid, and only some sulphureted hydrogen. In one I noticed the gases rising from small holes similar to those of the springs at camp 37 [at the head of Pine Creek], and from the top of little cones in its bottom. One, (106°), the largest, and like Turbid Lake, a reservoir, bubbled along its shore, while its banks were filled, like it, with small active and remains of small extinct springs; one 20 feet from the last, 3 feet in diameter, temperature 120°, lead-colored deposit, reacted for sulphureted hydrogen, iron, alumina, and soda, sulphides, sulphates, and hyposulphites, and became very acid after standing four hours.§

* Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, in 1873, p. 192.
† Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, in 1873, p. 298;
‡ *Ibid*, p. 192.
§ Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, 1873, p. 298.

These springs at present, therefore, represent the last stages of thermal activity, and were once probably connected in some way with the Sulphur Hill Springs.

LAKE BUTTE SPRINGS.

North of Lake Butte, between it and the mouth of Turbid Creek, but nearer the former than the latter, is a small group of hot springs and steam jets. They are near the shore, on the east side of the beautiful bay* that lies east and south of Steamboat Point. There are four or five principal springs on the slope of a bluff or hill that is bare of vegetation, and covered with a reddish deposit, on which there is, in a few places, a deposit of alum. The highest temperature observed was 192° F., and the lowest 110° F. Below these about a quarter of a mile are a few iron springs, on the side of the butte near the base. The average temperature here was about 170°. Common salt was observed in some of the springs, but sulphur, silica, and iron appeared to be the principal deposits of this group, which is comparatively unimportant. No connection with the springs of Steamboat Point, which is so near, nor with the Turbid Lake Group could be determined.

BRIMSTONE BASIN.

This name has been given to a basin of spring deposits, which are on the northwestern slopes of the ridge that extends southwest from Mount Stevenson. It is about a mile east of the lake, and covers an area of about 3 miles in extent. It is easily seen from a distance, the white deposit on the slopes rendering it quite conspicuous, and the sulphurous odors greet the visitor some time before he reaches the place. At present there are no warm springs at this locality, although there are many places in the channel of the small creek which bubble with sulphureted hydrogen. The deposit is generally white, mingled with yellow and blue clay. Sulphur is abundant, and it is the source of the sulphureted hydrogen. The stream draining this basin is strongly impregnated with alum, and has been called Alum Creek. Its channel is coated with sulphur, and the water is milky in its hue. Not even the trace of a spring with a temperature above that of ordinary water could be found, although the deposits give evidence that some time in the past this was the seat of very active thermal springs.

COLD SPRINGS AT HEAD OF PINE CREEK.

While the cold springs of Brimstone Basin are described, it may be interesting to mention the springs at the head of Pine Creek, described as follows byDr. Heizmann:

> Around us, buried in the woods, we discovered a number of circular springs 10 to 15 feet in diameter, each on a small terrace. The water of these (temperature, 37°–42° F.) was clear and limpid, revealing a soft, grayish bottom, pierced here and there by little round holes, from which bubbles of gas ascended at intervals of one minute exactly. It showed no reaction of any kind, while the gas collected was suspected to be sulphurous-acid gas, on account of its bleaching litmus paper. Tests for carbonic acid and sulphureted hydrogen were frequently but fruitlessly applied. These springs were remarkable because of being *sui generis*, none analogous having been found afterward in the other hills or valleys of this region.†

This locality may represent a stage of decay many steps in advance of Brimstone Basin.

*This is the bay that was originally named Mary's Bay, but on the map the name has been given to the bay north of the point.

† Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, 1873, p. 296.

SPRINGS ON WEST OR SOUTHWEST ARM OF YELLOWSTONE LAKE, AT HOT SPRINGS CAMP.

This group of springs was first visited by the Doane-Washburn party, in 1870. It has not been visited by the writer since 1871, but a portion of the notes then taken were not used in the preparation of the report for that year, which was only a preliminary report.* The locality is known as Hot Springs Camp, and has become a favorite resting place for those who go to Yellowstone Lake from the Upper Geyser Basin. To one who has just seen the powerful geysers of the latter region the springs of this group will not seem to present much of interest, yet these springs are not uninteresting. They are divided into mud springs or mud puffs, pulsating springs, and quiet springs. They are scattered along the shore of the lake for about two or three miles. The upper ones may be considered as a subgroup, although the interval between has numerous springs scattered along the shore of the lake.

The lake shore is composed of thick siliceous deposits which have been worn into a bluff of 20 to 25 feet in height. Most of the springs are situated on this terrace, although a number are at the water level and extend out into the lake, where they have formed, in two instances, cones which are surrounded by the water of the lake. The deposit extends out beneath the waters of the lake, and numerous points of bubbling attest the presence of spring orifices at various points in the lake. The deposit forming the shore or bank is laminated, and on it is a considerable thickness of broken up geyserite, which in some places has been cemented into large masses.

Lower Group.—The springs that first attract attention are the cones in the lake. One of these we named the "Fish Pot," from the fact that persons standing on this cone may catch trout in the lake and, without moving from their position, cook them in the spring without taking them from the hook.

The cone has been built up by laminæ of the siliceous deposit until it has a height of three feet above the level of the lake. Its shape is that of a truncated cone, and the water in the spring on top has a temperature of 160° F.† A spring on the shore north of this gives a temperature of 143° F. These springs affect the temperature of the surface of the lake, as we found on bathing in it. A layer of hot water is on top of the cold.

South of the Fish Pot, along the lake shore, is a line of springs with the following temperatures: 191°, 130°, 153°, 154°, 153°, 153°, 141°, 191° F. These are large springs with deep basins, in hard deposits. Some have an overflow, while others were quiet, although they may, and doubtless have, periods of increased action. The water is beautifully colored, of an azure tint, as in the springs of the other regions. One of the boiling or throbbing springs is divided by a bar or bridge of deposit into two basins.

A few hundred yards back from the lake shore there are the—

Mud Puffs.—The mud puffs are situated in a bank of clay (to which their peculiar character is due) of bright pink and red colors. The basin is about 50 feet in diameter, and the center is a seething mass of very finely divided mud, which on drying is lighter in color, and becomes a hard mass resembling chalk. Around the edges of the basin are small conical mounds of mud, about a dozen in number, of 2 or 3 feet height, from which the mud is spurted at irregular intervals to a height of 3 or 4 feet with a thud-like noise.

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*See introduction, Report of U. S. Geol. Surv. of Terr., 1871, p. 165.

†All the temperatures given of this group were taken in 1871, unless otherwise stated.

FIG. 5.—Hot Spring Cone on west arm of Yellowstone Lake.

These mud puffs resemble closely the mud puffs in the Fountain Group of the Lower Geyser Basin of the Fire Hole. The center of the basin is depressed in the same manner, and the mud cones or mounds are similar. The mud forming the latter has about the consistency of putty. The variation in the character of the mud springs, as I have mentioned in previous reports, depends on the amount of water supplied to the springs. When we saw these springs the mud was thick and tough.

In the immediate neighborhood of the mud puffs are numerous mud springs of all consistencies. Some are simply turbid springs; others have thin muddy water of white, red, or yellow colors, and some are thick mud springs resembling mud puffs.

One red turbid spring gives a temperature of 190° F.; a white one north of it is 182° F.; a second white one 142° F.; and other turbid springs have temperatures of 134° F., 176° F., 132° F., 174° F. In the south end of this subgroup the temperatures are 190° F., 146° F., 163° F., 185° F., and 168° F.

North of these are clear springs of 10 to 50 feet diameter and 40 or 50 feet depth, usually with funnel-shaped orifices. In some of these the ultramarine and sea-green tints are beautifully shown. They are probably pulsating springs. One is particularly noticeable, having a diameter of about 50 feet and a temperature 173° F. Further north the springs are lake-like in character, the water standing over large areas. In many of the springs the soft leathery-looking substance noted in the Shoshone Basin and in the Geyser Basins of Fire Hole River is abundant. The surface is generally brilliant in color, while underneath it is brown or black. It fills some of the basins to a considerable depth, although on the surface it is about 2 inches in thickness. It resembles jelly in some places, and is no doubt "*viandite*," the new variety described by Mr. Golschmith in Part III of this report. In some of the lower layers it is seen in a solidified state, and is more like the harder varieties of other varieties of the geyserite.

Still further north the temperatures of twenty-four or twenty-five springs were taken and found to range from 140° F. to 185° F.

The character of the deposits about the silicious springs of this locality is not so fine as in the Fire Hole Geyser Basins, and the ornamentation is much less. Dr. Heizmann, speaking of this group, says "the temperatures range from 70° to 180°, and all evolve carbonic acid; a few only sulphureted hydrogen."* He gives the deposits as silica, iron, alumina, magnesia, lime, soda, sulphides, sulphates and chlorides, and classes the springs with those of the Fire Hole Valley.†

None of the specimens of the silicious deposits collected by us have ever been analyzed. The mud I found in 1871 contained iron, alumina, lime, and silica. Specimens of the mud collected by the Washburn Doane party in 1870 were analyzed and found to contain silica and alumina as the principal constituents. These analyses will be given in Part III of this report.

Underneath the silicious deposits which line the shore of the lake at this locality are modern lake deposits—sandstones composed of disintegrated volcanic rocks (obsidian, &c.) and indurated clays.

Upper Group.—I did not visit this group in 1871, and the following description is taken from Professor Comstock's report, he having seen them in 1873, before he came to the Lower Group:

Like most of the collections within the limits of the ancient lake basin, this cluster contains a number of bowls, which emerge directly from the silty deposits, the con-

* Report of Reconnaissance of N.W. Wyoming, by Capt. W. A. Jones, 1873, p. 304.
† *Ibid.*, p. 304.

tents of which are, therefore, more or less contaminated by the admixture of insoluble ingredients. Near the lower end of the group a small, muddy flat runs back from the shore, which appears to have been the bed of an ancient stream, if not the channel of a recent creek during seasons of flood. On this are situated several mud bowls and a number of orifices of smaller dimension, in which the agitation is not powerful enough to render the contents turbid. Nearer the shore there are several large, clear, or nearly clear, springs, which constantly overflow, sending their surplus into the lake. The little stream which carries off the waste is so highly heated that one cannot bathe with comfort in its track, except by wading for some little distance into the lake before venturing opposite its entrance. Several mud pots occur at a higher level, just north of the flat on which the above are located. South of this point, at a still higher level, there are what may be called three clusters of springs, although they are not widely separated. The first collection comprises a set of half a dozen bowls of varying dimensions, which emerge from the summit of a kind of terrace of old hot spring deposits, 15 feet above the level of the lake at low water. In several of these the vapor issues with considerable force, but with a seething rather than a puffing sound.

One spring has a large bowl about 4 feet in diameter. Back of these the members of the second cluster issue from a silty area, for which reason the contents are mostly turbid or muddy. The third group is further from the lake and more elevated than the others, and may be said to combine, in a measure, the features of them all. The products are as varying as the varying character of the springs would suggest. The mud pots deposit about the usual proportion of ferric hydrate in addition to the other ingredients, and the amount of iron dissolved in the water of the clearer springs is apparently large, judging from the amount of colloid and confervoid growth, which exists wherever favorable conditions are present for such accumulations. The ornamentation of the margins of the clearer bowls is comparatively simple, and raised rims are almost entirely absent. Hydrated alumina is a prominent ingredient, and in some of the ancient deposits it is blended and intermingled with the silicious accumulations in a very interesting manner. In the past, as now, there has evidently been a close connection between this group of springs and the Yellowstone Lake, for all the bowls are situated in a section which has been worked over by the beating of the waves upon a beach, and the ancient deposits have been greatly modified since their formation by the same action.*

Recapitulation of springs of Yellowstone Lake.

Name.	Number of springs.	Highest temperature.
		°F.
Sulphur Hills Group	10+	
Turbid Lake Group	11+	190
Steamboat Springs	7+	192
Mary's Bay Group	10	192
Lake Butte Springs	7	192
Brimstone Basin		
Springs on West Arm	66	191
Total number of springs	112+	

So far as known, we have no large geysers in the groups of springs surrounding Yellowstone Lake.

CHAPTER V.

PELICAN CREEK SPRINGS.

The springs on Pelican Creek may be divided into three groups, according to their location, viz, "Lower Group," "Three Forks Group," and "West Pelican Springs."

Lower Group.—Dr. Hayden, in 1871, visited these springs, which are

*Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, 1873, pp. 233, 234.

really a portion of the Lake Springs, although more conveniently described here. He writes:*

In the valley near Pelican Creek a few springs are issuing from beneath the crust, distributing their waters over the bottom, and depositing the oxide of iron, sulphur, and silica, forming the most beautiful blending of gay colors. Although the waters of the springs are 160° F., yet the channels are lined with a thick growth of mosses and other plants, and in the water is an abundance of vividly-green algous vegetation.

The spring here described by Dr. Hayden was visited by Professor Comstock in 1871 and named the Green Spring. He says:

At the further edge of this deposit [red ocher] is a magnificent hot sulphur spring, the stream from which sinks after running a few rods, then passes over the surface again along the edge of the ore bed, finally discharging into Pelican Creek. The temperature of the water, according to Dr. Heizmann, is 104° F. Large quantities of a slimy, green *cryptogam* grow in the bed of the stream, which suggests the name, Green Spring, proposed at the head of this section.†

Dr. Heizmann says:

Although a few of these springs steamed and gave off the ordor of sulphureted hydrogen, none bubbled carbonic acid. Curiously, the red bank contained carbonate of iron. * * It is of mixed consistency, color, and texture, portions being soft and oily to the touch, others hard and irrefragable; from dark to light red, with purple and brown intermixed; compact or loose, and these differences not owing to the depth from which taken.‡

Animal life occurs in one spring.

On the iron deposit described above there is, some little distance to the right of the sulphur spring, a cold iron spring in which, as indicated on the topographical notes of 1871, the water has a temperature of 66° F.

The springs of this lower group are situated near the trail crossing of Pelican Creek, about a mile and a half from the mouth of the creek.

Three Forks Group.—These springs, which are few in number and comparatively unimportant, are in the broad upper valley of Pelican Creek, near the mouth of West Pelican Creek. There are a number of springs scattered along the creek, some in the stream and others on the banks. Many of them are hot and of considerable size, but the majority are dead or dying—cold springs being the rule. There are a few old geyser cones of hard siliceous deposit, but as geysers they are now extinct.

WEST PELICAN CREEK SPRINGS.

The following description is kindly furnished by Mr. W. H. Holmes:

Pelican Creek flows to the south along the eastern border of the Park, near the base of the Yellowstone Range. West Pelican Creek is a small branch of this stream that comes down from the highlands to the northwest. About three miles above its junction with the main stream it emerges from the low hills and meanders an open valley whose gently sloping sides rise to the height of 1,000 feet or more.

In approaching this valley from the timbered hills to the north the first object that attracted my attention was a column of steam that appeared to issue from the hillside at a considerable elevation above the creek.

Descending to the creek at its exit from the hills and crossing obliquely to the south, I soon reached the spot from which the column of steam ascended. Some 300 feet above the creek I came upon a caldron of boiling mud which presented the usual appearance of the mud springs so common in this region. The pool is about 10 feet in length by 7 in width, and is surrounded by a low rim of dried mud. The gray liquid mud is kept in a constant state of agitation by the rising of great bubbles of gas from the vent beneath, and slender jets are thrown to the height of 5 or 6 feet. Surrounding the main caldron are a number of small fumeroles, all of which have made

* Report of U. S. Geol. Surv. of the Terr. for 1871–1872, p. 136.
† Report of Reconnaissance of N. W. Wyoming, p. 194.
‡ *Ibid*, p. 298.

considerable deposits of yellow sulphur. A cave-like vent at the lower end of the pool keeps up a constant hissing and roaring. The air in the vicinity is loaded with the peculiar odor of sulphureted hydrogen.

This part of the valley seems to have been the site of many ancient springs, as the rhyolites which form the lower slopes and the heavy breccias which form the summits of the hills seem to be much altered by solfataric action.

About half a mile farther down the valley and only a few rods from the creek I came upon another group of hot springs and steam and sulphur (?) vents. The central feature is a broad shallow basin, partly filled with yellowish-gray water, which is kept constantly pulsating and bubbling by rising gases which issue from innumerable vents in the bottom of the basin. An area of some 20 yards in diameter surrounding this uncanny pool is covered with hillocks of whitish and reddish clay, from which issue small jets of steam or muddy water.

On the opposite side of the creek, near the base of the hill which borders the bottom land, is a boiling spring or geyser worthy of note. The pool of slightly turbid water is about 12 feet in diameter. The spring issues from the bank at the north side of the pool. The jets of water, which are driven upward with considerable force, strike a projecting ledge of tufa and are thrown obliquely upward to the height of 10 or 15 feet. The action is almost constant, but the flow of water is exceedingly slight. Descending the creek 2 miles farther, I came out into the open terraced valley of the main stream.

To the geyser described above by Mr. Holmes I have given the name "West Pelican Geyser."

PELICAN CREEK MUD VOLCANO.

In Lippincott's Magazine for July, 1880, Dr. S. Weir Mitchell describes a mud volcano, which, at first, I thought might be on the West Pelican; but after carefully reading the description, I have concluded that it is the one described to us in 1871 by some of our men, and which was said to be east of us as we traveled up Pelican Creek. Another thing that confirms this view is that the West Pelican Springs are only about 13 miles from the lake, and the camp from which Dr. Mitchell started to visit the mud volcano was 18 miles from the lake, and, moreover, he ascended the hills on the east side of the valley and descended on the far side. His description is as follows:

A gradual rising ground, made up of soft sulphureous and calcareous earth, was crowned by a more abrupt rise some 35 feet high, composed of tough gray clay. This was pierced by a cone of regular form about 30 feet across at top and 5 feet at the bottom. On the west, about one-third of the circumference was wanting from a point 6 feet above the lowest level, thus enabling one to be at a distance or to stand close by, and yet see to the bottom of the pit. The ground all around and the shrubs and trees were dotted thick with flakes of dry mud, which gave, at a distance, a curious stippled look to the mud-spattered surfaces. As I stood watching the volcano, I could see through the clouds of steam it steadily emitted that the bottom was full of dark-gray clay mud, thicker than a good mush, and that, apparently, there were two or more vents. The outbreak of imprisoned steam at intervals of a half minute or more threw the mud in small fig-like masses from 5 to 40 feet in air with a dull, booming sound, sometimes loud enough to be heard for miles through the awful stillness of these lonely hills. It is clear from the fact of our finding these mud patches at least 100 yards from the crater, that at times much more violent explosions take place. The constant plastering of the slopes of the crater which these explosions cause tends to seal up its vent, but the greater explosions cleanse it at times, and all the while the steam softens the masses on the sides, so that they slip back into the boiling caldron below. As one faces the slit in the cone there lies to the right a pool of creamy thin mud, white and yellow, feebly boiling. It is some 30 feet wide, and must be not more than 20 feet from the crater; its level I guessed at 16 feet above that of the bottom of the crater.

After an hour's observation near to the volcano, I retired some 50 feet, and, sheltering myself under a stunted pine, waited in the hope of seeing a greater outbreak. After an hour more the boiling lessened and the frequent explosions ceased for perhaps fifteen minutes. Then of a sudden came a booming sound, followed by a hoarse noise, as the crater filled with steam, out of which shot, some 75 feet in air, about a cart-load of mud. It fell over an area of 50 yards around the crater in large or small masses, which flattened as they struck. As soon as it ended I walked towards the crater. A moment later a second squirt shot out sideways and fell in a line athwart the mud-pool near by, crossing the spot where I had been standing so long, and cover-

ing me as I advanced with rare patches of hot mud. Some change took place after this in the character and consistency of the mud, and now, at intervals, the curious spectacle was afforded of rings of mud like the smoke rings cast by a cannon or engine-chimney. As they turned in air they resembled at times the figure 8; once they assumed the form of a huge irregular spiral some ten feet high, although usually the figures were like long spikes, or, more rarely, thin formless leaves, and even like bats or deformed birds.

Recapitulation of Pelican Creek Springs.

Name.	Number of springs.	Highest temperature.
		° F.
Lower Group	2+	160
Three Forks Group	5	.....
West Pelican Creek Springs	4	.....
Total number of springs noted	11+	.....

This table is, of course, very incomplete, as the areas indicated were but cursorily examined and all the springs are not enumerated. The following are the geysers:

Name.	Interval.	Duration.	Maximum height.
			Feet.
West Pelican Geyser	.....	Constant	75
Pelican Creek Mud Volcano	Not known	.....	*75

* The Mud Volcano, as noted by Dr. Mitchell, has periods of about half-minute eruptions, during which the mud is thrown 5 to 40 feet. The height given here is during the main eruption.

SECTION II.—SPRINGS ON MADISON RIVER DRAINAGE.

CHAPTER VI.

GIBBON RIVER SPRINGS.

Gibbon River was named by Dr. Hayden in 1872, in honor of General John Gibbon, United States Army, who had partially explored it. It rises opposite the waters of Gardiner's River, and flows in a southerly direction for about 15 miles, when it turns eastward and, after a course of about 6 miles, unites with the stream from the Fire Hole Geyser Basins just at the head of the Upper Cañon of the Madison.

In 1871 we were told of springs existing at the head of Gardiner's River, and on the streams opposite, but did not get any detailed description, nor did we visit them. Mr. P. W. Norris visited this region in 1875, and mentions it in his report for 1877,* and in his reports for 1878 and 1879 there are fragmentary descriptions of some of the springs.

The entire course of the river is in volcanic rocks, and where we have open valleys there are deposits of clays, in which there are mud springs.

The spring areas on Gibbon River are some six in number. The three most important of these will be described in detail further on. Near the head of the main spring are some sulphur vents and dead springs, much like those at the head of Obsidian Creek, just across the divide from the head of Gibbon River. They are unimportant and will not be further described. West of these fumaroles and north of the main Gibbon Basin is a locality that has never been visited. It is indicated on the map at the head of a small stream that joins the river in the broad open valley north of the Monument Basin. Great volumes of steam were noticed rising from it, and it is probable that it is the site of an important geyser. The two other localities which will not be described in detail are those of Geyser Creek and the one on the west side of the broad open valley. Their position is indicated on the geological map of the Park.

GIBBON GEYSER BASIN.

The Gibbon Geyser Basin covers an area of about 6 square miles, and is one of the most interesting within the limits of the Park, as here we have a geyser that has broken out within a short period. Mr. P. W. Norris is probably the discoverer of the basin. In his report for 1877 the accompanying map does not indicate the locality, although, on page 13, he says he passed from the forks of the Fire Hole, via Gibbon River, &c., to the Mammoth Hot Springs. On the map accompanying his 1878 report, he indicates the locality as Fire Hole Basins, and on the map of the succeeding year calls it Norris Geyser Plateau. We have decided, however, to retain the name Gibbon Geyser Basin, so that it will be uniform with the names of the other localities. Norris built his wagon road through the basin in 1878, and soon after it was finished we passed over it and visited the springs described in this chapter. In none of his reports does Mr. Norris give any detailed description of the springs, and we believe the following description, with the accompanying map,

* Report upon the Yellowstone National Park, by P. W. Norris, p. 13.

is the first published. He refers to them on page 6 of his report for 1878 and page 16 of the report for 1879.*

Our time in this basin was limited, and we mapped only the springs in the immediate basin through which the wagon road passes.

In the following table is a list of the springs of which the temperatures were recorded, and following it is a description of the springs that were mapped, the numbers corresponding with those of the accompanying map. The relative position of these springs will be appreciated by comparing this map with the geological map of the Park.

Table of Gibbon Geyser Basin Springs.

Number or name.	Size.	Temperature.	Temperature of air.	Time of observation.	Remarks.
		°F.	°F.		
2	Fissure 10 feet long	197	....	.....	There are several vents near by.
4	2 by 3 feet is size of fissure; outside basin is 20 feet diameter.	195	....	.....	Steam bulges slightly.
5. Emerald Spring	40 by 50 feet diameter	*186	....	.....	Handsome yellow-green pool.
9	25 feet diameter	*190	....	.....	Constantly bulging.
14	25 by 30 feet	155	....	.....	Turbid bulging pool.
16	8 feet diameter	182	63	10.45 a. m.	Bulger, sending water foot or two.
24. Opal Spring	.....	90	....	.....	Opalescent tint to water.
45. Echinus Geyser	40 feet diameter	180	....	.....	
68. Pearl Geyser	Basin 25 feet diameter; central orifice 5 by 6 feet.	162	....	.....	Water rises and falls periodically.
70	Basin is 20 feet diameter	180	....	.....	
79	.....	180	....	.....	Muddy sulphur spring.
.....	.....	175	....	.....	Small sulphur pool near No. 79.
81	10 by 15 feet	175	42	10 a. m.	Black sulphur spring.
82	.....	186	....	.....	Clear green sulphur spring.
83	30 feet diameter	176	42	.....	Sulphur spring.
96	10 feet wide	161	....	.....	Do.
97	10 feet diameter	142	51	12.15 p. m.	Green sulphur pool.
98	.....	117	....	.....	Large basin with three fissure-like openings at the bottom.
101	15 feet long	102	60	1 p. m.	Milky-blue pool in salmon-yellow basin.

*On the edge.

NOTE.—This table gives only those springs of which the temperatures were recorded.

DESCRIPTION.

Springs Nos. 1, 2, 3, 4, 5, 6, and 42 are located on the hill which separates the two main groups of the basin. The first four are west of the wagon road on a bare summit, and are described as follows:

No. 1 is a milky, green, sulphur pool about thirty feet diameter, in which the water is violently agitated, splashing from three to four feet above the basin, and frequently sending spurts to the height of 8 or 10 feet with a great escape of steam. The temperature could not be taken as the bank surrounding the spring was soft and unstable. If at any time there is an overflow from the spring it probably goes to the gulch north of it.

Nos. 2, 3, and 4 are at a little lower level than No. 1.

* Mr. Norris, in his report for 1881, p. 57, mentions several geysers, calling them Monarch, New Crater, Emerald, Vixen, &c., but I have no means of identifying them. The Monarch, he says, spouts 100 to 125 feet at an interval of over 24 hours and lasts 20 to 25 minutes.

No. 2 is a fissure about 10 feet in length with a spring about a foot in diameter at one end. This is a sulphur-lined opening in reddish tinted hard geyserite or sinter, in which the water has a temperature of 197° F. Near No. 2 are a steam vent and a turbid pool of about a foot in diameter.

No. 3 is a milky-looking pool about 3 by 3 feet, in which the water is gently boiling. Sulphur appears to be characteristic of these springs.

No. 4 is a basin 20 feet diameter, of broken geyserite, in which is a second basin in hard deposit with a fissure-like center, which is sulphur lined, and gives forth steam. In this the temperature is 195°F.

No. 5, emerald spring, is somewhat concealed in the timber, and is a handsome, yellowish emerald-tinted pool, measuring 40 by 50 feet. The basin is sulphur lined and has a gray border. The water boils at one end, and has a temperature of 186° F. on the edge of the spring. There is considerable overflow, which goes to the southwest.

No. 6, *Locomotive Spring.*—This is a boiling sulphur mud-hole about 12 feet in diameter with a raised margin about 3 feet high, composed of mud coated with sulphur. A stake with the name Locomotive was found near the spring, probably put there by some one of the party when building the wagon road. The spring is across the road from No. 1 on somewhat higher ground. Near it is a pool, and the surface is perforated with steam vents and mudholes.

No. 42 is on the slope of the hill south of No. 5, and is a turbid sulphur spring that spouts. Back of it are several sulphur mud-pots, and the gulch beyond is full of sulphur vents.

Most of the springs to be described now are in a broad flat depression or basin measuring about 200 by 300 yards. It is from 50 to 100 feet in depth, and besides the springs enumerated contains hundreds of sizzling holes, steam vents, and mud pots. The sketch map accompanying this report will give the best idea of these springs. The hill on the east contains a number of springs, and Nos. 7 and 8 are in a gulch near the wagon road on the south side. Nos. 33 to 37 are at the north edge of the flat which carries the drainage from the group, while Nos. 39, 40, and 41 are on the south side.

No. 7. *Black Geyser* is a small spouter at the head of a gulch, where the wagon-road turns to go around the group. It is in dark bluish-black deposit of spouts, with a great deal of steam to the height of 10 feet. The water is milky-hued, and has a strong odor of sulphur, which is probably the cause of its turbidity. The water fluctuates.

No. 8 is a steam vent or fissure 2 by 3 feet, in a rock in the gully below No. 7.

No. 9 is a whitish pool in a gray basin, about 25 feet diameter. The central orifice measures 2 to 3 feet diameter, and from it there is a constant bulging which throws the water in the pool into waves. The temperature on the edge is 190° F.

No. 10 is a collection of muddy pools, receiving water from No. 9.

No. 11 is three mud springs. The upper one is a light-colored bulger. The lower ones are lead-colored.

No. 12 is a greenish-white pool surrounded by steam vents and mud-pots.

No. 13. is a collection of greenish mud-holes.

No. 14 is a turbid milky pool, 25 by 30 feet, which bulges slightly in the center and has a temperature of 155° F.

No. 15 is a constant spouter, throwing a mass of water 5 feet into the air, and occasional spurts 15 to 20 feet. The temperature was not taken. The geyser is at the end of the pool.

No. 16 is a bulger, sending water to the height of a foot or two from the center of a basin which measures 8 feet diameter. The water is turbid and has a temperature of 182° F.

No. 17 is a white boiling spring 8 feet in diameter.

No. 18 is a semi-turbid spring, about 10 feet in diameter, and bulges.

No. 19 is a milky-tinted pool, 15 feet long by 6 or 8 feet wide.

No. 20 is a bulging pool 15 feet in diameter.

No. 21 is a circular basin, 3 feet in diameter, with a bright red bordered hole in the center, from which water and steam are alternately spurted. Around No. 21 are a number of vents, sulphur holes, and turbid springs. The surface is too treacherous to allow of temperatures being taken.

No. 22. *Grindstone Springs.* This is a collection of circular mud mounds with small circular orifices, about a foot each in diameter. The mounds are several feet in diameter, and resemble a lot of grindstones as much as anything. No. 22 and 22*a* are the most perfect. Between these springs and the road are a number semi-turbid springs.

No. 23 is on the right of the road, and is a greenish sulphur pool. Near it is a lake-like pond.

No. 24. *Opal Spring* is on the mound forming the Eastern boundary of the depressed basin. It has bluish-white water, which flows from the spring over ocher-yellow terraces. Between the spring and the depressed basin there is a slope covered with minute terraces, over which the water flows from a small fissure. The tint of the water in the spring is probably due some substance held in suspension, the temperature being only 90° F. On the mound above the spring there are fissures and holes, from which both steam and water escape. One has a peculiar, trough-like, small basin, from one end of which the water spurts. There are also old crater-like holes, with small mounds about 6 inches in height.

No. 25 is a long bluish-white pool on the summit of the mound. There is a small spurting geyser at one end. The pool is constantly agitated, and there is a large escape of steam.

No. 26 is a bulging and spouting milky-hued spring, with three centers of ebullition on the slope of the hill. It is 8 by 15 feet, and the hill back of it is coated with sulphur and alum. A great quantity of steam escapes.

No. 27 is a fissure back of No. 26. There are several holes from which steam escapes in large volume. One of the holes is yellowish-white, another white, and all boil vigorously.

No. 28 is a spouter on the line of the fissure of No. 27. The water is clear, in a basin of hard geyserite measuring 4 by 8 feet.

No. 29. *Mound Geyser.*—This is a flat-topped mound or platform measuring about 12 by 15 feet, and rising 6 inches to a foot above the general level. The orifice in the center of the platform measures 3 inches by 1 foot, and sends out with great force alternately a spurt of water and steam. In this it resembles No. 21.

No. 30 is a dark-gray sulphur pool about 20 feet in length. The edge is sulphur-lined, and at one end the water bulges and boils violently. Between Nos. 29 and 30 there are sulphur-lined vents.

No. 31 is a semi-turbid sulphur pool which bubbles slightly.

No. 32 is a creamy-white thin-mud pool, in which the mud or muddy water is in constant agitation.

In the valley below these springs there are large ponds, or lakes, of greenish-yellow tint. The largest receives water from the springs included under Nos. 29 to 32. There appears to be no outlet, although the

water may at some time have escaped by way of the gulch leading to the springs of group containing Nos. 88 to 94. The hills or mounds north and west of this sulphury basin with the lake-like ponds are generally white tinged with red, presenting the appearance of a burnt district; the red color is due to the oxidation of the iron in the deposits.

Springs Nos. 33 to 38 are at the base of the hill which forms the western boundary of the depression.

No. 33 is a double spouter, throwing water from 2 to 5 feet into the air. Between this spring and the lakes there are numerous vents, mudholes, and spurting springs.

No. 34 is a bright-yellow sulphur spring about 4 by 4 feet. Back of it, on the slope of the hill, is a pink steam vent, and below is a bluish. drab triangular turbid spring.

No. 35 is a spring 15 feet in length, with five centers of ebullition. Near No. 35 are several round turbid pools.

No. 36 is a dark bluish-gray spring 4 by 3 feet, with dull yellow and red border. There is considerable overflow from this spring.

No. 37. *Yellow Crown Spring.*—This is a lemon-yellow-hued mound spring, with an oak-leaf shaped margin. The mound is 5 feet in diameter and about a foot high. The basin is 2 feet deep and sulphur-lined. Bubbles escape gently from the small central orifice. Between Nos. 36 and 37 there are a number of small holes.

No. 38. Two brown-lined pools, about 2 by 3 feet, surrounded by bluish-gray geyserite.

No. 39 is a large lake-like muddy pool.

No. 40 is a boiling spring about 10 feet in diameter. In the flat below it are a number of vents.

No. 41 is a dark-gray, almost black, boiling spring, 13 or 14 by 18 feet, with a black and gray border. Between Nos. 40 and 41 there are several springs at the head of a small gulch, and on the hill back of these springs there are steam vents in the timber.

The group to be described next contains all the principal geysers of the "Gibbon Basin" here described, and is the one first entered when we follow the road coming from the south. After passing by springs Nos. 67 and 71 the road descends into a broad flat, which it crosses and leaves again near the minute geyser, where it begins the ascent of the hill on which springs Nos. 1 to 5 are located. The springs are found mainly to the right or east of the wagon-road and are somewhat concealed by trees. There are three gulches leading into the flat, and in these are found a number of important springs. The one that attracted notice first, in 1878, was the great steaming vent on the side of the hill opposite the point where the road enters the basin. A huge column of steam ascends from this with a great roar. This is located on the map as No. 43, *Steamboat vent.* It consisted of two roaring steam-holes on the side of the hill, that look as though they had just burst through the surface, and the gully leading towards the ravine to the south is covered with sand that appears to have been poured out during an eruption. Trees standing in the line of this sand-flood are dead, and a number uprooted and covered with sand, and some of the trees back of the vents have had their foliage killed, but it had not yet fallen from them. Everything seems to point to the fact of the recent formation of this vent. There is no deposit marking the opening, although stones surrounding the hole are beginning to have points of geyserite deposited on their upper surfaces. Whether it is now a geyser with regular periodical eruptions I cannot determine, but that water has been poured from it admits of no doubt, as the gully leading from it presents all

the evidences of the flow of water. This may have occurred when the vent burst open.

The description just given is from my field-notes for 1878. Since writing them out Mr. Norris informs me that in 1875 the vent had no existence, and in his report for 1879 he gives the date of its formation as August 11, 1878. In the same report also he says (on page 16) that it has settled down to business as a very powerful flowing geyser, which has a double period; one eruption occurring every half hour, and projecting the water to a height of 30 feet, and the main eruption occurring every six or seven days, the action being long continued, and the column attaining a height of nearly 100 feet. When we saw it in 1878 there was no water in sight, and the steam escaped in a steady column. This promises to be the most interesting geyser in the Park, as it will afford most important data as to the building of the deposits and the age of the geysers. This subject will be discussed in another portion of the report. The study of the future of this geyser and of the "New Geyser," to be described farther on, promises to be most interesting.

No. 44 is a large gray mud-pot, 20 by 23 feet, situated in the valley below No. 43. It boils vigorously.

No. 45. *Echinus Geyser.*—This was so named because the pebbles around the basin have some resemblance to the spine-covered sea urchin. The basin is about 40 feet in diameter, and throws a mass of water 15 to 20 feet into the air at intervals the length of which we were unable to determine, on account of our short stay in the basin. The border of the spring is gray and red or reddish brown, coated with black and bluish gray spinous-like processes. The coating of geyserite is thin, and the underlying rocks are exposed at places, as though this were a comparatively new geyser. Below the basin deep red and maroon colored terraces spread for some distance from the geyser, and it is probable that the geyser has at times eruptions on a grand scale. The eruption which we witnessed lasted about three minutes. I think this geyser marks a step in geyseric action beyond that shown by No. 73, which itself marks a stage beyond that shown in No. 43.

No. 46. *Vermillion Spring.*—This is a bright red muddy spring 8 feet in diameter.

No. 47 is a large sulphur spring in a basin about 35 feet in diameter, with several centers of ebullition.

No. 48. Pond-like turbid pool boiling in the center.

No. 49. Large greenish pool with several centers of ebullition.

No. 50. Muddy steam vent on the side of the hill back of No. 48. The opening is 3 feet in diameter.

No. 51 is a large pool about 30 feet in width with three centers of ebullition. Back of it is a gray boiling mudhole 6 by 10 feet.

No. 52 is a deserted geyser hole with a little water at the bottom. There are steam vents near it.

No. 53 is a bubbling spring 2 feet in diameter. Back of it are sulphur springs.

No. 54. *Double bulger.*—Two bulging springs with rims and a pool back of them. Below, it is a large pond.

No. 55. *Pebble Geyser.*—This, as far as we could determine, is one of the most important geysers in the basin. It is a tube 6 inches by 2 feet, in a mound of hard semi-translucent geyserite. When we visited it on the 13th of September there was no water visible, but the surrounding basin gave evidence that it is a geyser. Its name was given to it from the abundance of rosetted pebbles in the basin outside of the tube. On the 14th we saw from a distance two eruptions of this geyser,

which we estimated to reach a height of over 50 feet. The interval between them was one hour and fifteen minutes. They lasted a few minutes only.

No. 56 is a blackish, muddy, boiling spring, 8 by 12 feet.

No. 57 is a gray mudhole, 12 by 20 feet.

No. 58 is a yellowish mud pool, near a large pond-like quiet pool.

No. 59 is a bluish-gray boiling pool, 20 feet in diameter.

No. 60 is a collection of yellow sulphur springs near some large pools.

No. 61 is a hole in the rocks on the bank of the creek.

No. 62 is a boiling spring with two centers of ebullition. It opens into the large pond.

No. 63 is a black sulphur mudhole, 15 by 20 feet, in the timber above No. 60.

No. 64. Mud pools and springs above a large pond at the head of a grassy gulch. The rocks near these springs appear to be obsidians.

No. 65 is a bulging sulphur spring, 6 by 8 feet, on a mound, over which the water flows in waves, forming small terraces.

No. 66 marks the site of some old geyser holes, in which the old deposit has become converted into hyalite. The sediments were deposited layer on layer, and are to a great extent covered with the soil.

No. 67 is a clear, vault-like spring, 6 by 10 feet, in which the water is 18 inches below the top. There are other springs in the neighborhood of this.

No. 68. *Pearl Geyser.*—This geyser is named from the white pearl-like appearance of the deposit around the spring. The basin is about 25 feet in diameter, inside of which is a bowl 5 by 6 feet, from which the water bulges, and, judging from the surroundings, at times spouts. The basin has a greenish-gray and yellow-gray border with beautiful white rosette-like formations on the outer basin, and pearly deposit lining the edge of the inner basin. The water rises and falls, and had a temperature of 162° F. when it was filling only the inner basin.

No. 69. *Cradle Mud Spring.*—This was named from the curious cradle-like mound which the spring has built. At one end is a hood-like mound 2 feet high, from beneath which the mud spurts. The orifice or basin is about 3 feet wide and 5 feet long. The mud is of a dark bluish color and rather thick.

No. 70 is a small geyser on a hard flat mound of gray and reddish geyserite. The basin is about 20 feet diameter and the central orifice only 18 inches across. The temperature was 180° F.

No. 71. Large clear greenish tinted hot steaming pool, near the wagon road as it enters the basin from the south.

No. 72 is a boiling spring near some sulphur springs.

No. 73. *New Geyser.*—This consists of two fissures in trachyte. They are parallel, measuring about 15 feet in length by 4 feet in width at the top and a foot below. In these the water is boiling vigorously. The surrounding rocks are colored brilliantly with red, orange, and yellow. There is no mound and the rocks of the fissures are just beginning to get a coating of geyserite. This probably represents the first condition of a geyser after the fissure fills with water, marking perhaps the second step in the history of a geyser, No. 43 marking the first. The gully leading from the fissures and the character of the surroundings present proof that there are eruptions, but we did not witness any. When we visited them the water was some distance below the top and was in vigorous action. It was perfectly clear, but its temperature was not ascertained.

No. 74 *Minute Geyser.*—This geyser, which is close to the wagon road

on the right as it begins the ascent of the hill, was named by Mr. Norris. It is a fissure 3 feet by 10 feet, in the center of a basin measuring about 25 feet diameter, on a mound of blackish-gray, hard geyserite. It is probably a fissure in trachyte which is being gradually coated with the deposit formed by the evaporation of the water after the eruptions. The following eruptions were noted:

Eruption No. 1.—Spouted at 4.28 p. m., throwing water 30 feet. Eruption lasted 2 minutes.

Eruption No. 2.—4^h 29^m 45^s: Spurt. 4^h 29^m 55^s: Eruption began; interval from beginning of first was 1 minute 55 seconds. 4^h 30^m 16^s: Eruption ended heavy; lasted 21 seconds.

Eruption No. 3.—4^h 31^m 15^s: Eruption began; interval from beginning of No. 2 being 1 minute and 20 seconds. 4^h 31^m 25^s: Eruption ended, having lasted 10 seconds.

Eruption No. 4.—4^h 32^m 30^s: Eruption began; interval from beginning ot No. 3 was 1 minute and 15 seconds. 4^h 32^m 50^s: Eruption ended, having lasted 20 seconds.

Eruption No. 5.—4^h 30^m 10^s: Eruption began; interval from beginning of No. 4 was 4 minutes and 40 seconds. 4^h 3^m 32^s: Eruption ended, having lasted 22 seconds.

Judging from these few observations the geyser has been very well named. The water is thrown to a height of 30 to 40 feet. Between Nos. 73 and 74 there are several muddy pools, and back of the Minute Geyser is a sulphur pool.

The springs next described are on the right of the wagon road near the gap in the low hills through which the water from the springs just described finds its way from the basin.

No. 75 is a small spouter sending up steam and water in alternate puffs, the former preponderating.

No. 76. Old steam sulphur vents and mudholes.

No. 77. Steaming mud craters in the timber.

No. 78. Steam vent.

No. 98. Three fissures in hard deposit, opening into a large basin, in which the water is quiet. Near it is a sulphur spring and steam vents.

No. 99 is a steam vent back of No. 98.

No. 100 is still farther back of No. 98 in the timber.

No. 101 is a milky-blue pool 15 feet long, with a scalloped edge and temperature of 102° F.

Below this subgroup of springs the water from the first group described joins that from the main basin and spreads out on a broad flat, which has numerous sulphur pools and mud-pots and ponds of standing water. These form the group to be described last, as follows:

No. 79 is a boiling sulphur spring of turbid water having a temperature of 180°. Another small one near it has a temperature of 175°. There are also a collection of mud pots and lake-like sulphur ponds on this flat.

No. 80 is a large lake-like sulphur pond, as shown on the map.

No. 81 is a black sulphur bubbling spring 10 by 15 feet, with a temperature of 175°.

No. 81*a* is below No. 81, and is a bubbler 3 feet in diameter.

No. 82 is a clear greenish sulphur spring with a temperature of 186°. Near it is a spouter 2 feet in diameter.

No. 83 is a circular bubbling sulphur spring about 30 feet in diameter, with a temperature of 176° F.

No. 84 marks the location of a number of shallow sulphur pools and steam vents.

Leaving this group and proceeding northward through the timber we come to No. 85, a collection of mud pots 2 to 3 feet in diameter, with white mud.

No. 86. A collection of simmering holes and steam vents.

No. 87. Sulphur holes and vents. These are not far from the main creek that is north of the basin.

Returning through the timber, the next subgroup is opposite that of No. 79, and is composed of the following:

No. 88. Double sulphur spring.

No. 89. Milky green sulphur spring 10 by 12 feet.

No. 90. Small green spring.

No. 91. Steam hole in rocks.

No. 92. Large green pool, about which there are numerous sulphur simmering holes.

No. 93. Mud pot, with thick white mud.

No. 94. White mud pot, 10 feet diameter, surrounded by vents and mud-holes.

The two following are near the large pool, No. 80, already mentioned, viz:

No. 96. Sulphur spring 10 feet long, with temperature of 161° F.

No. 97. Green sulphur pool, 10 feet in diameter, with temperature of 142° F.

There are several points in connection with this Geyser Basin that are particularly noticeable when we review its numerous springs. They are:

First. The absence of any very great accumulation of deposits, such as are seen in the Geyser Basins of Fire Hole River.

Second. The newness of some of its most important geysers.

Third. The abundance of iron and sulphur in the deposits.

It is, I think, evident that here we have the newest development of thermal action to be found in the Park, not only because we have a geyser which dates only from 1878, but because when we examine the other geysers we find that the deposits have not yet reached any considerable development. The oldest geyser in the group, if we judge from the accumulation of deposits, is the Pebble Geyser.

Southwest of the springs just described and about a mile distant, in what he calls the Upper Cañon of the Gibbon, Mr. Norris says there is a collection of red pulsating geysers.* In his report for 1878† he speaks of them as follows:

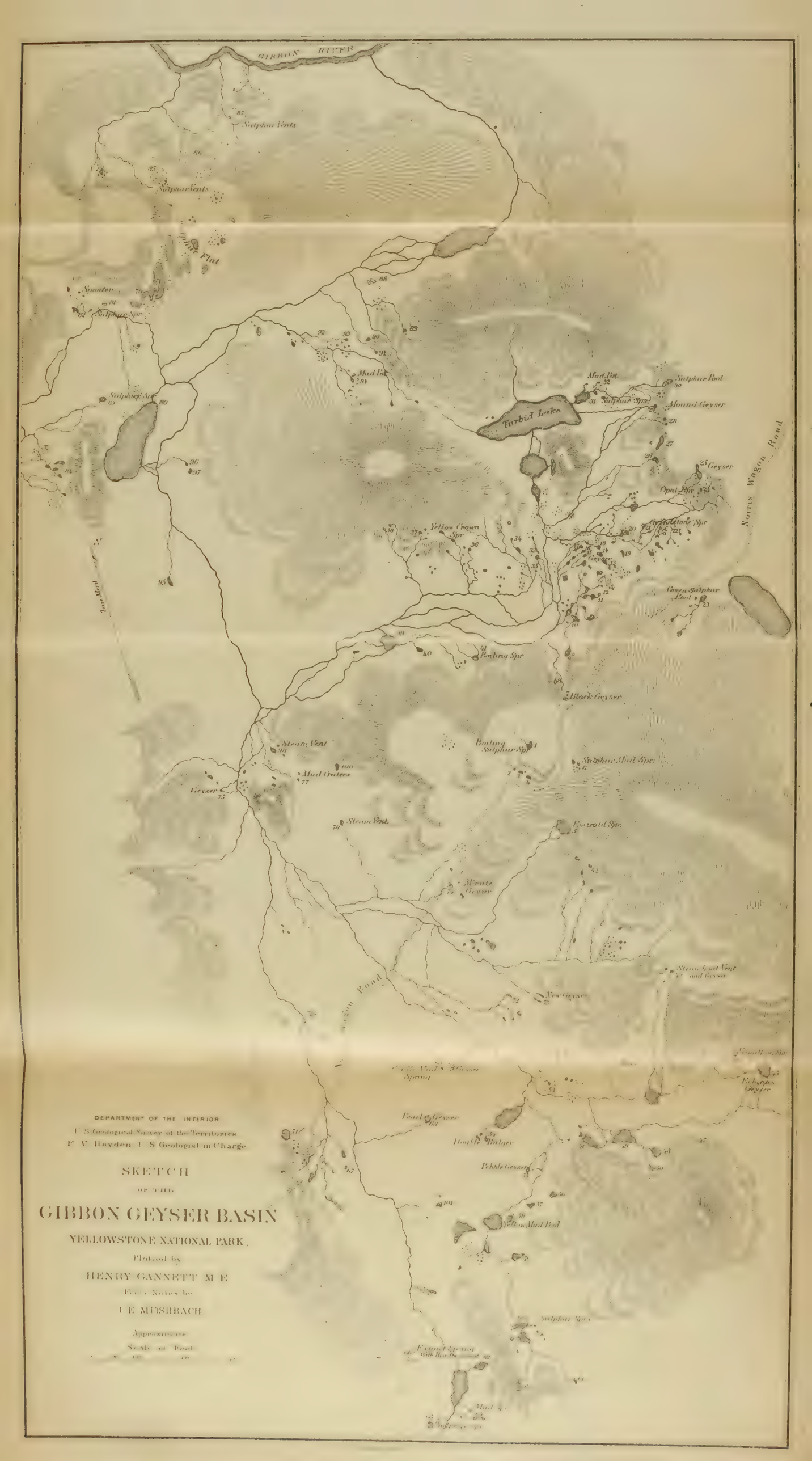
> Along and near the upper cañon of the Gibbon are pulsating geyser cones of both yellow and crimson, paint springs, and rivulets of nearly every color, geysers throwing their jets, some at least 100 feet, at an angle of 40° to 60°, instead of vertically, as in the old basins.

This is probably the same as the Red Geyser Basin he speaks of in his report for 1877 (page 13).

MONUMENT GEYSERS.

This collection of geysers, named by Col. P. W. Norris, is on a spur of the plateau on the south side of the open valley above the head of the lower cañon of Gibbon River. The group is about 1,000 feet above the level of the river, and the columns of steam can be distinctly seen from the open valley. I was unable to visit them from lack of time, and the

* Report on the Yellowstone National Park 1879, p. 16.
† Report on the Yellowstone National Park 1878, p. 6.


GIBBON RIVER
Sulphur Vents
Sulphur Vents
Mud Flat
Spouter
Sulphur Spr.
Mud Pot.
Sulphur Spr.
Mud Pot.
Sulphur Pool
Sulphur Spr.
Mound Geyser
Turbid Lake
Geyser
Opal Spr.
Yellow Crown Spr.
Green Sulphur Pool
Boiling Spr.
Black Geyser
Steam Vent
Mud Craters
Geyser
Boiling Sulphur Spr.
Sulphur Mud Spr.
Steam Vent
Emerald Spr.
Morning Geyser
Norris Wagon Road
Steamboat Vent and Geyser
New Geyser
Iron Pond
Pearl Geyser
Double Bulger
Pebble Geyser
Yellow Mud Pool
Sulphur Spr.
Mud Spr.
DEPARTMENT OF THE INTERIOR
U. S. Geological Survey of the Territories
F. V. Hayden U. S. Geologist in Charge
SKETCH
OF THE
GIBBON GEYSER BASIN
YELLOWSTONE NATIONAL PARK.
Plotted by
HENRY GANNETT M.E.
Field Notes by
J. E. MUSHBACH
Approximate
Scale of Feet

following description is from Mr. Norris. He says the group is spread over somewhat less than 5 acres, and contains numerous hot springs, among which are twelve geyser cones from 2 to 20 or 30 feet in height, in form similar to the Liberty Cap of Gardiner's River. The majority are in a dead or dying condition. One has its orifice horizontal in the summit of the cone. There is at least one powerful geyser in the group, and whenever there is water from an eruption it pours down the slope of the spur in a series of cascades.

About 2 miles down the cañon is another small group in which there is a geyser which we call "Oblique," that spouts out obliquely over the road.

LOWER GROUP ON GIBBON'S FORK.

This group is situated about half a mile above the junction of Gibbon's Fork with the Fire Hole River. The springs were first visited probably by General Gibbon, who partially explored the stream which now bears his name. He directed Professor Bradley to the springs, who describes them in his report for 1872.* Still later Dr. Hayden and myself visited them,† and the description I shall give will be compiled from these reports.

The springs are on the north side or right bank of the river in a valley, about a mile in length and a half mile in width. These are on a terrace at the base of the hills back from the river, above which their elevation is from 80 to 100 feet, the deposit covering several acres. The water flows from a dozen or more different openings. The largest spring is in reality a small lake or reservoir, at one end of which are two orifices, one of which is constantly boiling.

It is of an irregular form, something like the outline of a goat-skin bottle, with the spring in the mouth of it, about 200 feet long by from 50 to 90 feet wide in its main part, while the narrowest part of the neck is from 10 to 15 feet wide.

The temperature I obtained in 1872 was 140°. Professor Bradley describes the temperature as follows:

The temperature at the point of nearest safe approach to the center of ebullition was 146°; 100 feet distant, the water escaping from the pool gave 126°; while the farthest point of the pool gave 120°. The exit flow was rapid, along a channel averaging about 3 feet wide by 9 inches deep. This had built up its banks a few inches above the surrounding level, and at two or three points the deposit had even bridged the stream.

The spring at the end of this pool is a pit from 2 to 3 feet in diameter and about 15 feet in depth. In this, which is constantly boiling, the water is projected 1 to 3 feet into the air, above the surface of the pool. Two small streams flow into this lake-like pool, having their origin in two springs that have temperatures of 135° F. to 150° F. One of them is a pulsating spring, and the water spouts about a foot. A short distance east of the pool are two springs with temperatures of 100° F. and 122° F.

A second pool, quadrangular in form, measuring 50 feet on a side, is described by Professor Bradley. The center of ebullition could not be approached, and the temperature along the edges of the pool was only 113°.

The smaller flows varied from 110° up to 134°, and in one case up to 150°. Several old openings along the outer edge of the terrace were long since deserted, and the flow is now only from higher levels farther back. The deposit thus appears to stop up the channels and so to force the water back until it finds or makes new openings in the

* Report U. S. Geol. Survey of the Terr. for 1872, 1873, p. 230.
† *Ibid.*, pp. 55 and 159.

disintegrating jointed masses of the porphyry which form the underlying stratum and the hill behind the terrace. At only one point is there a strong flow below. This is on the immediate bank of the stream, and the temperature being only 92° indicates a mingling of cold and hot springs.*

About the center of the valley there is an old spring basin composed of three terraces, rising about 18 inches one above the other, in much the same manner as the terraces on a larger scale at the Mammoth Hot Springs. Here the springs are extinct, and the terraces overgrown with grass. There is considerable lime in the deposits, and a coating of iron lines the channels of the small streams that carry away the overflow of the springs. The varied colored jelly-like deposit is abundant. The springs have doubtless passed their most active period.

Dr. Hayden, speaking of the deposits, says:

The old deposit has now become dry, but it was formed into quite large terraces, somewhat like those made by the calcareous springs, with larger reservoirs or pools, instead of the more delicate ones in the Geyser Basin. In the reservoirs and along the channels of the living springs are most beautiful masses or locks of vivid green confervoid vegetation, floating in the water like locks of wool. There are several other fine springs, but mostly of low temperature, with the inner surface of the basin covered over with a thick, deep rusty yellow, leathery substance, which gives them the look of a tan-vat.†

Recapitulation, Gibbon River Springs.

Name.	Number of springs.	Highest temperature.
		° F.
Gibbon Geyser Basin	101	197
Monument Basin	12	.....
Lower Group	8	150
	121+	.....

The following are the known geysers, with the points that have been obtained:

Name.	Group or location.	Interval or period.	Duration of eruptions.	Maximum height.
				Feet.
Black Geyser	Gibbon Basin	.....	.....	10
No. 15	....do	.....	Constant	20
Mound Geyser	....do	.....	.....	.....
Steamboat Vent	....do	Has a double period, one being every half hour, and the other every 6 or 7 days.	.....	100
Echinus Geyser	....do	Not known	3 minutes	20
Pebble Geyser	....do	1 hour 15 minutes	.....	50
Pearl Geyser	....do	Not known	Not known	.....
New Geyser	... do	.....	.....	.....
Minute Geyser	....do	75 to 100 seconds	10 seconds to 2 minutes.	40
Monument Geyser	Monument Basin	.....	.....	.....
Oblique Geyser	....do	.....	.....	.....

The tables just given are not, of course, complete, but give all the data obtainable up to the present time.

* Bradley's Report, p. 231.

† Report U. S. Geol. Survey of Terr. for 1872, 1873, p. 55.

CHAPTER VII.

LOWER GEYSER BASIN OF FIRE HOLE RIVER.

The Lower Geyser Basin is a wide valley that extends southward from the junction of the East Fork of Fire Hole River with the main stream. Several smaller branches come in from the west, above the mouth of the East Fork, and one on the east. The entire area is between 30 and 40 square miles, and over this the springs are scattered in groups. In this chapter we have catalogued 693 springs, including the Egeria springs, all of them being shown on the map. There are 17 known geysers in this Basin. The central portion of the valley extending from Twin Buttes to East Fork Butte is a wide flat plain of some 6 or 7 square miles, partially timbered, but for the most part bare and covered with spring deposits or marsh. The view of this plain on a frosty morning is interesting, as columns of steam are seen rising from all parts of it. To Lord Dunraven it gave the impression "that some modern cities of the Plain had been overwhelmed, and had so lately sunk amid flames into the bowels of the earth that the smoke of their ruins was still ascending through white heaps of smoldering ashes."* The general elevation of the basin is 7,236 feet, and above this the surrounding plateau rises from 400 to 800 feet, the slopes being heavily timbered.

Geology.—As to the geology of the Lower Basin the reader is referred to the report of Mr. Holmes for the details. The rocks of the plateau are rhyolites, and in the remnants of lake-beds, which are formed in the buttes scattered through the valley, we have the evidence of the former existence of a lake. Professor Bradley was inclined to think that the two Geyser Basins are remnants of a huge crater, as he found dips towards the Basin in the rocks on several sides.† I am, however, inclined to think that these inward dips are due to a depression in the basins caused by a deep-seated fissure, through which the thermal waters are forced to the surface. The general slope of the plateau, interrupted only by this depression, continues to the south or southwest, indicating a flow towards the south or southwest.

Professor Comstock thinks that the Geyser Basins not far in the past were overflowed by siliceous waters, because—

> In some portions of these districts the trees are marked for 2 feet above the base of the trunk with a white incrustation, giving them something of the appearance of the whitewashed trees in an orchard.‡

I think this condition can be more readily explained as follows: The hot water flowing from the springs surrounds the bases of the trees and kills them. Upon evaporating, the sediment deposits about the trees and the water standing upon this is carried up the trunk by capillary attraction, and evaporating from the outside of the trees leaves the white siliceous deposits referred to above as the result of inundations, having a depth of 2 feet.

History.—In the early accounts of this region this locality was spoken of as the Burnt Hole, and as such was vaguely indicated on the maps from hearsay. Thus, on the map accompanying Raynold's report of his expedition of 1859–'60, the region east of Henry's Lake, across the mount-

*The Great Divide, p. 257.
†Report U. S. Geol. Survey, 1872, p. 241.
‡Reconnaissance of Northwestern Wyoming, 1873, p. 258.

ains, on the Madison River, is marked Burnt Hole, and was probably so called from Bridger's description of the Fire Hole Basins. It is too far north, but is evidently meant for the Lower Basin.

In 1863, a party of prospectors on their way from Snake River to Virginia City passed through the Lower Geyser Basin. Capt. W. W. De Lacey speaks of it as follows:

> In another mile we reached the head of a small stream, the water of which was hot, and soon entered a valley, or basin, through which the stream meandered, and which was occupied on every side by hot springs. They were so thick and close that we had to dismount and lead our horses, winding in and out between them as we best could. The ground sounded hollow beneath our feet, and we were in great fear of breaking through, and proceeded with great caution. The water of these springs was intensely hot, of a beautiful ultramarine blue, some boiling up in the middle, and many of them of very large size, being at least 20 feet in diameter and as deep. There were hundreds of these springs, and in the distance we could see and hear others, which would eject a column of steam with a loud noise. These were probably geysers, and the boys called them "Steamboat Springs." No one in the company had ever seen or heard of anything like this region, and we were all delighted with what we saw. This was what was afterward called the "Lower Geyser Basin" of the Madison, by Professor Hayden.*

The Washburn and Doane expedition of 1870 passed through the Lower Geyser Basin on their return from the Upper Basin to Virginia City, but they did not devote any time to its examination, considering it mainly a basin of extinct springs, although they remarked upon the great quantity of water flowing from them. They, however, described the Great Spring of the Egeria Group with more interest.

The Lower Geyser Basin was the first visited by the survey in 1871, and we at first supposed we were in the Upper Basin. Fortunately we made on that account a much more careful examination of the springs. Our descriptions, published in the report for 1871, are the first details of the Lower Basin ever published, at least in book form. As this basin possesses less attractions to the ordinary traveler than the Upper Basin, a shorter stay is usually made in it, and on account of this and also from the fact that the springs are scattered over so large an area, less is known of the periods of its principal geysers than of the geysers of the Upper Basin, which are not only more numerous but also closer together, so that several may be observed at the same time from one point of view.

In the following pages I have described the springs in groups, after first describing the springs of the East Fork of the Fire Hole. The latter are beyond the limits of the Lower Basin, but it is more convenient to consider them here, as they are too few in number to warrant a chapter being devoted to them, and they are of the same character as the springs of the latter.

EAST FORK SULPHUR SPRINGS.

First Group.—This group of springs is on the southern branch of the East Fork of the Fire Hole, about 2 miles from the forks in the valley from which the Howard road ascends to the plateau to reach the level of Hayden's Valley. The small stream coming from the group is warm and filled with bright green vegetation. The springs occupy an area of about 200 square yards. The deposits are mainly silica and sulphur. The first spring met with has a temperature of 182° F., and is on the right bank of the creek, and is a clear sulphur spring with a light yellow deposit. The overflow is considerable. On the opposite side of the creek, a little back from the stream, is another sulphur with a tempera-

*A Trip up the South Snake River in 1863, in "Historical Society of Montana, Contributions," Vol. I, page 132.

ture of 193° F. Above the latter, and close to the creek, is a spring in which the water rises and falls about once a second with an impulse and sound like a grunt. Its temperature is 192° F. Still farther south a small branch brings in the water from about five springs. The largest of these is a boiling spring with a circular basin 5 feet in diameter, in a black deposit. Its temperature was 172° F. Back of this and tributary to it is a small spring, with a temperature of 17° F. To the right of these two springs is another cluster of three springs. The upper one of these is a clear sulphur spring, the hottest in the basin, having a temperature of 199° F. Next to it is a white sulphur spring, in which the mercury recorded 183° F., and below the latter a hot sulphur spring of 189° F. in temperature. Back of these springs there are steam jets in a crust, the under side of which is lined with crystals of sulphur. Crossing the creek, the upper spring on the right bank is found. It is a small white-sulphur spring, with a temperature of 128° F. Above this spring the water in the creek is cool.

Second Group.—About a half mile below the forks there are two springs on the left side of the East Fork. They have beautifully clear water. One is about 20 feet in diameter, and the other about 40. The temperatures are 142° F. and 192° F. In one of them the basin into which the water flows is coated with ferric oxide.

Third Group.—Nearly 3 miles below the forks a warm creek comes into the East Fork from the south. This has its origin in a basin similar to the one already described. Dr. Hayden visited it in 1871, and describes it as follows:

> About 2 miles below our first camp [near the forks] we passed a pretty little stream flowing down from the hills, with the channel lined with a delicate veil of creamy sulphur. We followed it up the valley a half a mile and came to another group of springs similar to those just described [First Group]. There were a number of steam vents, with the same variety of delicate linings and shades of coloring. In some of the springs iron predominates over the sulphur, and to these we gave the name of Iron Springs. In others the sulphur is in excess, and those we called Sulphur Springs.*

LOWER GEYSER BASIN.

The numbers given to the springs correspond with those on the map, each group having its separate numbers. In the case of the Sixth or River Group we were somewhat hurried in our work, and therefore all the numbers do not appear on the map, but each spring is described and almost all of them are actually located on the map. The theoretical boiling point in the Lower Basin is 199°.3 F., but the thermometers were tested and showed that water actually boiled at 199° F.

FIRST OR EAST FORK GROUP.

This group includes a large number of springs which are located mostly in small ravines and along the foot of the hills on the south side of the East Fork of the Fire Hole River. Although extensive it is not of very great importance, there being no very large basins or even a good sized geyser, although there are several small spouting springs which might be termed *pseudo geysers*, as they throw jets of water several feet into the air.

The maps which have been made do not show the springs of this group in such a manner that they can be identified, so that I have found

* Report of U. S. Geol. Survey for 1871, p. 103.

it impossible, except in a few cases, to compare my notes of 1878 with those of 1871. The highest temperature recorded in 1871 was 198° F., which agrees quite closely with the highest (198½° F.)which I obtained.

In the following table I have given all the springs of which I took the temperatures, with the descriptions that are sufficient, except in a few cases, which will be noted after the table:

Table of the First or East Fork Group.

Number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1	8 feet diameter	136	11 a. m.	48	Brown-lined.
2	10 by 15 feet	138			Much like No. 1.
3	10 feet diameter	132			Circular, green-lined pool.
4	2 by 4 feet	129			White-rimmed, brown basin, on a mound of broken geyserite.
5	15 by 25 feet	130			Green and brownish lined, irregular-shaped spring, on a mound of broken fragments of geyserite.
6	Pool 8 by 3 feet spring back to beneath a rock.	*190			Clear spring, with red pool.
7	7 by 8 feet	185			Clear water, with a red-lined pool just below it into which it spreads.
8	10 by 12 feet	126			Red-lined basin.
9	2 by 3 feet	196			White-bordered basin.
10	2 by 3 feet	197			Boiling spring in white deposit, with pointed edge.
11	Diamond shaped	196			Bubbling, yellow-edged spring, white and blackish basin.
		*a*190			Two small holes close to No. 11; *a* is nearest.
		*b*140			
12	4 by 6 inches	174			Small hole on opposite side of ravine from 10 and 11.
13	3 by 5 feet	172			White-bordered deep hole on plateau between the ravines.
14	8 by 18 inches	198			Spouting spring, in which the water rises and falls; yellow orifice in gray and black deposit, yellow-lined outlet.
15		198½			Spouter, with gray and yellow edge and white-bordered outlet.
16	2½ feet diameter	155			Yellow and white lined.
17	*a*=18 inches diameter	192			Two holes below.
	b=6 inches diameter	198			No. 16.
18	Triangular pool 2½ feet on sides.	170			Below 17, near creek.
		*a*160			Collection of holes near creek.
		*b*190			
19		*c*192			
		*d*188			
		*e*179			
20		195			Bubbler.
21		196			Bubbler.
22	3 inches diameter	184			Quiet spring.
23	1½ by 3 feet	180			Bubbles occasionally.
24		128			Red spring.
25		117			Quiet, red spring.
26		162			Light, greenish-tinted spring, with white border. Back of it is a bubbling hole.
27	3 feet diameter	140			Receives water from No. 26.
28		165	12.15 p. m.	57	White hole below 26.
29	4 by 8 feet	147			Double circular spring, yellowish-green basin, spreads out on red mound.
30		195			Bubbler, with other holes close by.
31	7 feet long	101			Pear-shaped spring, red-lined basin; two small red holes back of it.
32	4 feet diameter	157			Clear, yellow-gray spring on mound of white, broken deposit.
33	5 feet diameter	102			Red spring.
34	6 by 15 feet	116			Red pool below 27 and 28.
35	3 by 5 feet	143			Gray spring.
		108			Red pool near 35, almost extinct.
36					Spouting spring.
37		155			Quiet, gray spring.

*Spring.

Table of the First or East Fork Group—Continued.

Number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
38	2 by 4 feet	138			
39	6 inches by 1 foot	154			
40	A foot or two in diameter	165			Hard geyserite mound; bubbles and spouts a foot or more.
41	do	196			On mound with 40.
42	3 by 4 feet	110			In the grass.
43	A foot or so in diameter	162			On mound with No. 40 only, below in ravine.
44	do	163			
45					Dead hole on mound.
46		192	1 p. m.	58	Hole beneath rock on side of hill.
47	18 inches diameter	190			Hole with bubbler back of it. The water rises and falls.
48	2½ by 4 feet	112			Leathery-looking lining. This spring is on the water-way from 47.
		a190			Back of 48.
49	4 feet long, 18 inches to 2 feet wide.	200			Geyser cone constantly bubbling.
49a	7 inches by 1 foot	a193			Near 49.
		b196			Bubbling hole.
50		176	1.30 p. m.	55	Small, gray spring.
51	2 inches by 1 foot	195			Fissure on side of hill above 50.
52	10 by 30 feet				Pool in the grass, with other holes near it.
53	10 by 15 feet	156			Cavern-like pool.
54	2 by 8 feet	156			Bubbles escape from one end. Above this are other springs not yet taken.
55	25 feet diameter	*150			This spring is on flats in timber, near the trail between the river and springs grouped near No. 40.
56	3 by 5 feet	165			White pool in which sand bubbles up with water. Back of it are sizzling holes.
57	15 by 24 feet	95			Turbid pool.
58	6 by 10 feet	116			Holes in grass.
59	3 by 5 feet	118			
60		97			
61	Mound 18 inches diameter	186			
62		155			Hot ooze.
63	3 by 8 feet	117	2 p. m.	53	Red spring above white mound.
64	2 by 3 feet	100			Red spring, almost extinct, on a geyserite mound.
65		105			Quiet spring,
66		185			White-bordered springs.
67		165			
68		173			
69	2 by 4 feet	144			Red pool.
70		115			Red, slimy-looking oozes.
71		75			
72	10 by 10 feet	125			Greenish and reddish lined cavern.
74	9 feet long, 4½ feet wide, with overhanging edge 4 feet high.	150			100 yards below group of 69-72, in the timber.
75		130			Round, red, leathery-like lined spring.
76		97			Almost dead spring on white mound.
77	5 feet long	166			Pear-shaped pool.
78	Spring 8 by 18 inches, pool 15 feet long	170			Pool, with spring at end.
79	2 holes, each 4½ feet diameter.	161			White and funnel-shaped.
80	3½ feet diameter	146			Greenish-lined basin.
81	4 feet diameter	120			Spring in bed of small stream, leading from others.
82	3 inches diameter	140			
83	3 by 5 feet	171			Gray basin, with white border on outside.
84	Two springs, each about 3 feet diameter.	193			Two dark gray, almost black, holes.
85	3 feet diameter	116	3 p. m.	50	Small, red spring.

*On the edge of spring.

DESCRIPTION.

The springs included from No. 1 to No. 5 are on a sort of marshy plateau, which is bordered by low butte-like hills. They are evidently the remnants of what were once numerous springs, now overgrown with grass and converted into a marsh. The drainage from these springs

collects and runs into into a ravine, on the sides of which Nos. 8, 9, 10, 11, and 12 are situated. Nos. 6, 7, and 8 are a short distance back of 9 and 10, on more level ground, while No. 13 is farther up the ravine, on the left side, the same side with No. 12, only farther back from the ravine, and really on the plateau separating the two branches of the creek.

No. 6 is a clear spring, which gushes out from under a mass of conglomerate rock on the south side of the area which I have just described. The spring is actually beneath the rock, and outside spreads out into a red-lined pool measuring 3 by 8 feet. The temperature of the water as it emerges from the rock is 190° F. The conglomerate contains fragments of trachyte, and is a remnant of the lake deposits that once spread over this area.

No. 13 is a deep hole, obstructed by wood. It is 3 by 5 feet and has a white border. The water has a temperature of 172° F. I recognize this as a spring which in 1871 had a temperature of 169° F. The walls are very handsome in their ornamentation. In the ravine east of No. 13, but higher up, is the spring with the highest temperature; it is No. 15, and is on the east side of the gulch. It is a spouter, as is also its companion, No. 14. It has a gray and yellow edge and a white-bordered outlet. The temperature is 198½°.

No. 14 is perhaps the main geyser, and has a gray and blackish basin, with a yellow scalloped rim. The orifice is 8 by 18 inches. The water rises and falls periodically and spurts to a few feet. The temperature was 198° F. In 1871 the temperature recorded was 197° F. This difference is probably due to the difference in the thermometers used. Practically the temperature is the same. Back of these two spouts are a number of sizzling holes in the clay bank at the head of the small gulch, and below them a small pool of standing water.

Springs 20 to 23 are on the steep side of a hill on the east side of the ravine. On the top of the hill there are two small spouting holes in the rocks. They are not indicated on the map.

Springs 24 to 30 form a cluster, the drainage of which unites before it flows into the ravine. Only one, No. 30, has a high temperature (195° F.), and is a bubbler.

Nos. 31–33 are below the cluster of 24, &c., on the same side of the stream, and drain into it below the junction of the two branches.

Nos. 34 and 35 have no outlets, and are nearer the bluff.

Following along the foot of the hill, going east from 35, we soon come to No. 36, which is a small spouting spring on the side of the hill. Farther on are two quiet springs nearly extinct. Between them and the river there is a great deal of timber, most of which is dead. Next is No. 37, in a sort of hollow among rocks at the foot of a rocky slope. It is a quiet, gray spring, with a temperature of 155° F.

From No. 37 is some distance to the next cluster, the first indication of which is met with in Nos. 38 and 39, two small, unimportant springs. The main springs are in the gulch, some distance above the general level. No. 40 is a spouter, and No. 41 has a temperature of 196° F. Nos. 41, 43, and 44 are on the hard, geyserite mound with No. 40. In the grass about these there are numerous springs not included in the table, none, however, of any importance. Between them and 45, which is an extinct spring, there are other holes, and in the flat below numerous mudholes and pools are found.

Nos. 46 to 51 are comparatively small holes on the side of the hill. Most of the temperatures are high.

Nos. 52–54 are at the foot of the bluff, in a group of stagnant pools and holes of muddy water. There are other springs above these that were not included in the table, from want of time for their examination.

We now return to the foot of the gulch which contains the principal springs, and find springs 56 to 75 scattered along the foot of the bluff between the gulch and a ravine still farther west. The springs are sufficiently described in the table. Between them and the river are scrubby pines, among which are many old holes that were once springs. In the ravine above referred to springs 76–84 are situated. They are mostly of low temperatures, and all are small. This subgroup, with No. 85, which is a little farther west, completes the group on the south side of East Fork, with the exception of the Butte Group, yet to be described.

Springs on north side of East Fork.—In addition to the springs enumerated in the table there are four springs and a mud pot on the opposite side of the stream. They were not visited this year on account of the limited time at our disposal, so I copy from my notes of 1871 and 1872.

No. 1. This is a circular, funnel-shaped basin 6 feet in diameter, with clear water about 30 feet deep, and a temperature of 162° F. in 1871 and 164° F. in 1872.

No. 2 is another funnel 3 feet in diameter, with a circular, funnel-shaped basin with white porcelain-like sides tapering to an orifice of about 4 inches. Its temperature taken in 1871 was 170° F., in 1872 it was 178° F.

No. 3. This has an opening about a foot in width, in which the mercury recorded 174° F. in 1871, and 180° F. in 1872.

No. 4 is the largest, and is somewhat irregular in shape, measuring 16 feet in length by 6 feet in width. In 1871 the temperature was 156° F., in 1872 164° F.

The measurements given here are the correct ones, those given in 1871* being estimated. The differences in temperature not being constant are probably due partly to an actual difference in temperature on account of periodicity in action and partly to the difference in place of taking it.

Below these springs is a mud spring, the contents of which are an agitated mass of thick bluish mud, with a temperature in 1871 of 190, F. The crater or basin of this mud-pot is only about a foot in diameter.

Below these springs and below the Butte Group there are isolated springs along the banks of the East Fork, which have not been included in the catalogues and are not shown on the map. One of these, near the mouth of the stream, has a temperature of 197°, and is mentioned by Professor Bradley in the report for 1872 as having a mucilaginous deposit on the sides.

Some of the springs farther up have had cones, but all of them give evidence that their activity is diminishing.

BUTTE GROUP.

Below the springs included under the East Fork Group are four or five clusters of springs situated on the south side of the East Fork between and at the foot of the buttes, between which the trail passes out from East Fork into the open flat basin. Only the first cluster was visited for the purposes of examination this year. The others were carefully examined in 1871, and all are shown on the map.

First cluster.—This consists of about a dozen or more quiet springs at the foot of the Eastern Butte in a ravine. The temperatures of three springs were taken, viz, 140° F., 180° F., 150° F. The side of the hill back of these springs is stained with an iron deposit, and appears to be full of extinct spring holes and steam jets.

* Report for 1871, p. 182.

Second cluster.—The springs of this group are out on a flat place extending over most of the space between the river and the butte at the foot of which the first cluster is situated. Four temperatures taken here in 1871 are, 122° F., 145° F., 162° F., and 165° F. These, however, are but a few of the springs at this place, as the map shows.

Third cluster.—This includes the springs at the north base of East Fork Butte. Two of the springs are well up on the slopes. The following are temperatures taken in springs at the base: 126° F., 126° F., and 98° F. This cluster would be included with the fourth cluster, but the drainage of the latter is towards the main open basin.

Fourth cluster.—This comprises three or four springs between the buttes. They have temperatures of 157° F., 167° F., and 167° F. All the springs of the group are only of slight importance. I have referred to them simply to make the description of the basin as complete as possible.

CAMP GROUP.

The trail that follows down the East Fork of the Fire Hole River leaves the latter stream at the "Butte Group" and passes between the two buttes out into the broad open portion of the valley, which is here a wide, marshy tract covered with a rank growth of grass in most places. Turning southward along the west side of the marsh we soon reach the favorite camping place in the basin, on a small stream of good water at the edge of the timber, nearly two miles east of the Fire Hole River and a mile and a half from the East Fork. Back of this camping place, at the foot of the buttes, surrounded by timber which conceals them from view from the other portion of the basin, is a number of springs to which I have given the name of "Camp Group." They have never before been mapped, and are of considerable beauty and various in form, although there are no geysers among them. They are somewhat above the general level of the basin, on a flat place which narrows above into a ravine, and again spreads out into a marshy space that was once a spring area, as the grass-covered mounds now in it show. The following are the springs of the group:

Table of Camp Group Springs.

Number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1	Small oozing hole, 4 by 8 inches, on same mound with No. 2.	154	.....	....	There is slight overflow.
2	Two small mounds on a large mound; *a*, 16 inches by 1 foot; *b*, 1 foot by 2 feet.	*a*, 160 *b*, 162	.....	....	Hard, gray mound springs; are gray-lined. There is slight overflow.
3	Geyser? tube	172	.....	....	Water is low, but evidently rises and falls.
4	5 feet by 3½ feet	186	3 p. m.	45	Clear gray-lined spring.
5	3 feet diameter	102	.....	....	Iron-deposit lined.
5*a*	3 feet diameter	.....	.....	....	Dead hole between No. 4 and No. 10.
5*b*	Funnel	.....	.....	....	Water from No. 4 and No. 5 runs into this.
6	6 feet by 7 feet	136	.....	....	Greenish yellow funnel with pink-lined basin; overflow goes to No. 7.
7	10 feet long	115	.....	....	Red-lined basin.
7*a*	2 feet by 2½ feet	180	.....	....	Near No. 7, and is clear, gray-lined hole.
8	1 foot diameter	87	.....	....	Dead spring.
9	2 feet diameter	.....	.....	....	Water out of sight in hole.
10	3 feet by 3½ feet	118	.....	....	Red, quiet spring.
11	4 feet by 6 feet	.....	.....	....	Clear, gray spring, with overhanging walls of geyserite.
12	.....	127	.....	....	Large, red pool, close to No. 11; near by are other holes.

Table of Camp Group Springs—Continued.

Number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
13	Three springs; principal one is 5 feet diameter.	146	.....	....	Turbid springs.
14	8 feet by 15 feet.....	.....	.....	....	White mud-pot on the same hillside with Nos. 13 and 15.
15	7 feet by 12 feet.....	.....	.....	....	White cavern, in which water bubbles from among black pebbles.
16	30 feet diameter.....	92	4 p. m.....	46	Turbid spring in marsh.
17	7 feet diameter.....	120	.....	....	Nearly concealed in the grass.
18	Cone, 2 inches by 3 inches..	149	.....	....	On edge of stream.
19	.....	140	.....	....	Small, yellow-lined pool with white border.
20	3 feet wide; 1 foot high.....	182	.....	....	Flat, white cone. There is a thumping noise beneath the ground.
21	.....	.....	.....	....	Turbid pool.
22	Large pool.....	.....	.....	....	There are springs back of this stream flow through it.
23	3 feet by 4½ feet.....	136	.....	....	Red-lined.
24	25 feet diameter.....	136	.....	....	Turbid greenish pool; other springs near by in marsh.
25	Basin, 10 feet diameter; spring, 5 feet diameter.	136	.....	....	Quiet, gray spring; no outlet.
26	10 feet diameter.....	154	.....	....	Beautiful blue-gray basin with outlet.
27	15 feet diameter.....	139	4.30 p. m ..	43	Funnel-shaped, hard, greenish-yellow basin.
28	Number of boiling holes....	197	.....	....	Considerable overflow from these holes, which are very active.
29	15 feet diameter basin, with a triangular opening 5 feet on a side.	182	.....	....	Salmon-colored basin.
30	10 feet by 15 feet by 18 feet..	156	.....	....	Beautiful white basin, with blue-tinted water; cliff-like sides to the basin.
31	8 feet diameter.....	*a*, 154 *b*, 120	.....	....	Two greenish turbid holes.
32	20 feet diameter.....	143	.....	....	Large yellow and green lined cavern-like pool.
33	2 feet by 10 feet.....	200	.....	....	Fissure-like spring of clear boiling water. Steam escapes from constantly boiling water. Near by is a quiet gray pool.
34	Small holes	70	.....	....	
35		125	.....	....	
36		146	.....	....	

DESCRIPTION.

Nos. 1 to 12 form a subgroup, or cluster, south of the main springs and nearest to the camp. They are separated from them by a fringe of timber. Near No. 12 are a few mud pots, one of which is 6 feet in diameter and filled with a thick mud paste, which the stream throws into rosette-like masses in its escape. None of the springs in the cluster are very active nor are the temperatures high.

The main springs, 13 to 33, are in the space at the immediate foot of the butte. Between the butte and a spur on the south side of the space is a marshy area, in which springs 19, 20, and 24 are located.

Nos. 13, 14, and 15 are on the north side of the spur already indicated. Following up the ravine from these we come out into a broad, marshy valley, in which Nos. 16 and 17 are situated. No. 16 is a grassy mound raised about 2 feet above the level. It is 30 feet in diameter, and contains turbid, greenish water, in which the temperature is only 92° F. No. 17 is in the grass; below No. 17 and above are other holes not noted in the table, but which are shown on the map.

Returning now to the main group, we find that No. 28 attracts the attention first, on account of the amount of steam which escapes from

it. It consists of a number of small holes on the side of the butte. They are filled with pebbles, among which the water boils violently. There is a considerable overflow, and the temperature is 197° F.

No. 33 has the highest temperature (200° F.) in the group. It is a fissure 10 feet long by 2 feet wide, filled with clear, boiling water, from which steam is continually arising. Near it is a quiet gray pool.

The color of the water in a number of the springs in the group is very handsome. In the marsh are a number of vents and minor springs not included in the table.

SECOND OR THUD GROUP.

Following the edge of the timber south from the camp location, within about a half a mile we come to the Thud Group. In the previous reports this was indicated as the second group. It occupies an area of about 16 acres, and fronts the open portion of the basin. Back of it the slopes of the hills are well timbered. The timber separates the group from camp, and a few isolated patches of trees also stand between it and the Fountain Group. The group is named from one of the springs of the group, which makes a thud-like noise when the steam escapes. There are really two springs that have this thud sound, which fact has given rise to a little confusion. The name is given sometimes to the wrong spring. It should, perhaps, be given to the spring which is periodic in its action, and this is No. 3, which, in the description of 1872, was called Fungoid Spring. However, as both are thud springs, I have retained the names as there used, calling No. 4 the Thud *Spring*. It is not a geyser in the true sense, as no column of water is thrown out, so far as known.

Table of Second or Thud Groups.

Name and number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1. Lone Spring	9 by 16 feet; 4½ feet deep.	174	10.30 a. m.	....	Milky-hued water.
2. Stirrup Spring	8 by 9 feet; 5 feet deep.	186	.....	....	Yellow water-way.
		*187	.....	....	
		a, 195	.....	....	Small holes near No. 2.
		b, 194	.....	....	
		c, 181	.....	....	
3. Fungoid Spring	13 by 17 feet; basin, 6 inches deep.	Center, 165	.....	....	Thud Spring of 1871 maps.
		Edge, 163	.....	....	
		a, 190	.....	....	Small basin with two apertures.
4. Thud Spring	16 by 18 feet; 8 to 12 feet deep.	187	11.45 a. m.	39	Boiling at 3 or 4 centers.
5. Oak-leaf Spring	6 feet diameter; 15 feet deep.	189	.....	....	Greenish-tinted water.
Cone	2 feet high; 5 inches diameter.	Cone, 186	.....	....	The cone is near the main spring (5) on same mound.
6. Kidney Spring	Irregular, 15 or 18 by 6 feet; 1 foot deep.	177	.....	....	Beautifully colored outlet.
7. Cliff Spring	4 by 8 feet; 5 feet deep.	190	.....	....	Light greenish-tinted water.
8. Jug Spring	4 by 5 feet; 3 feet deep,	190	.....	....	Funnel-shaped basin.
9. Gourd Spring	10 by 15 feet; 12 feet deep.	165	.....	....	Square at the base, but generally of gourd shape.
10. Round Spring	5 feet diameter	140	.....	....	Greenish-brown basin.

* 2 feet below the surface.

DESCRIPTION.

No. 1. *Lone Spring.*—This spring is somewhat isolated from the rest of the group, being quite a distance to the east of them, on the side of a hill, at an elevation of about 40 feet higher. It has an ash-colored basin measuring 9 feet by 16 feet, with a white border, and the basin, which is somewhat funnel-shaped, is 4½ feet in depth. The water has a milky hue and a temperature of 174°.

No. 2. *Stirrup Spring.*—This spring has a basin measuring 9 by 8 feet, with a white rim raised about 6 inches. It is 5 feet deep, and the overflow is carried away through a lemon-yellow colored water-way. There are two holes in the bottom of this spring, from which the steam escapes, and a fissure also, which makes the spring resemble the head of an old woman with a cap on; the scalloped edge of the spring representing the ruffles of the cap, and the fissure the mouth, while the other steam-vents represent the eyes. The temperature at the surface was 186° F., and at 2 feet below 187° F. This agrees closely with that (188° F.) taken in 1872. Close to the spring are several small holes, in three of which temperatures of 195°, 194°, and 181° were obtained. The latter is probably the one which in 1872 gave a temperature of 182° F.

No. 3. *Fungoid Spring, or Thud Geyser* (Fig. 1, Plate VII).—This is the spring called Thud Geyser on the map published in 1871, but in 1872 was renamed from the fungoid-like masses that form the margin. It is 140 feet west of the Thud Spring (No. 4) and 345 feet south of the Oak-leaf Spring (No. 5). Its basin measures 13 by 17 feet and averages about 6 inches in depth. The deposit is pure white silicious, sinter-coated with yellow in the shallow basin. In the center of the latter is an inner or central basin, 5 feet in diameter and 7 feet deep, over which the water has a light-greenish tinge, which contrasts well with the white and yellow colors of the basin and rim. The latter resembles a margin of fungoid growths on short pedestals. They are gray-brown on top. The temperature over the central orifice was 165° F., and in the basin near the edge 163° F. This was taken when it was quiet. During the thumpings it is probably higher. Surrounding the basin is a mound of sinter over which two small streams, lined with orange-colored deposit, carry off the surplus water. On this mound, close to the main spring, are two small basins. One of them (*a*) has four openings, in which the water had a temperature of 190° F. just after the thumping in the main spring occurred. During the latter the holes were empty, but as soon as the thumping ended the water began to flow steadily from them.

The following are the observations on the main spring:

Began.	Duration.	Interval.
11. 00 a. m.	10m	
11. 23 a. m.	7m	23m
11. 38. 30 a. m.	7m	15m 30s

During the action the basin is full, but immediately afterwards the water falls. The observations were too limited to determine anything in regard to the regularity of this spring. The noise made is a dull, suppressed thud, which seems to be below the surface somewhere. There is a slight escape of bubbles.

No. 4. *Thud Spring.*—This spring is 375 feet southwest from the

Gourd, and measures 18 by 16 feet. The depth varies from 8 to 13 feet. This of course refers only to the basin of the spring, as at the bottom there are orifices the depth of which cannot be ascertained by the line. There seem to be three centers of ebullition, two of which are very active. At intervals of a few minutes there seems to be an accumulation of steam, the escape of which shakes the ground, making a thud-like noise, whence its name. On looking into this spring the water seems to have an inky-green color, and had a temperature of 187° F. The centers of ebullition are in constant action, boiling steadily all the time, but increasing at the time of the thud, which is a low, muffled sound like that in the Fungoid Spring. No data were obtained as to the duration or exact interval of the active periods.

No. 5. *Oak Leaf Spring.*—This is west of the Cliff Spring (No. 7) and north of the Fungoid Spring. The deposit surrounding it has a gray color, and the margin of the basin somewhat resembles a fringe of oak leaves. The spring is about 6 feet in diameter and 15 feet deep, and the water has a greenish tint, with a temperature of 189° F. About 7 feet from the spring, and on the same mound, is a small cone 5 inches high and 2 feet in diameter at the base, in which the temperature was 186° F. The temperatures taken this year (1878) are lower than those of previous years, the difference being due, probably, to a difference in activity in the spring. The 1878 temperatures were probably taken during a period of quiescence.

No. 6. *Kidney Spring.*—This spring has a very irregular renal shape, whence its name. There are two somewhat globular-shaped arms at right-angles to each other. One is 19 feet in length, and the other 15 feet, the average width being about 6 feet and the depth about 1 foot. The spring is fringed with large scallops, each one of which is made up of smaller ones. There are three fissure-like centers of ebullition, outside of which the basin is white. The temperature was 177° F. The surplus water flows from the spring through a beautiful channel lined with saffron and lemon-yellow colors. This spring is 180 feet from the Oak Leaf (No. 5).

No. 7. *Cliff Spring.*—This spring is 240 feet southeast of the spring (No. 6) last described, and 122 feet east of the Oak Leaf. It measures 4 feet by 8 feet, and is 5 feet in depth. The deepest portion is at one end of the spring, where there is a cavernous opening, overhung by a scalloped edge. The water here is of a light green color. At the other end there is a rugged fissure, to which the edge of the spring slopes from the surface, having the form in miniature of cliffs. These above the water have a brown color, and below a deep purple. The temperature of the water is 190° F., which is somewhat lower than that obtained in 1872. The overflow of water finds its way from the spring over an orange-colored bed.

No. 8. *Jug Spring* is named from a fancied resemblance of its shape to that of a jug. It is 123 feet from the Cliff Spring (No. 7), and 150 feet from Oak Leaf Spring (No. 5). It measures 4 feet by 5 feet. It is 3 feet in depth, and is funnel-shaped. The temperature was 190° F., which is higher than that (188° F.) taken in 1872.

No. 9. *Gourd Spring.*—This spring is somewhat like a gourd in shape, with a square base, and measures 15 feet by 10 feet. This basin, which is 12 feet deep, is in the center of a large, circular mound of siliceous material. Its temperature was 165° F. The bed of the small stream which carries away the overflow of the spring has a copious depost of iron, and a short distance below we find the gelatinous material (*viandite?*)f ound so frequently in springs of low temperature.

FIG 1 CRATER OF THUD GEYSER
LOWER BASIN OF FIRE HOLE RIVER.

FIG 2 CRATER OF FOUNTAIN GEYSER.
LOWER BASIN OF FIRE HOLE RIVER

No. 10. *Round Spring.*—This spring has never before been described. It has a globular basin about 5 feet in diameter, which is lined with greenish-brown deposit with a white orifice at the bottom. It is a quiet spring with a temperature of 140° F. Near it are several holes in the deposit, which mark the sites of springs that are now extinct.

Almost all the springs of this group have what may be termed globular basins, *i. e.*, basins which widen below the surface, having overhanging edges, and narrow again to fissures or tube-like orifices. None of them are at the boiling point, and all except No. 10 belong to the class of constantly agitated springs, although all have probably periods of increased activity, as noted in two of them. It is doubtful if any are real geysers, as the deposits surrounding them do not present any of the characters seen about the known geysers. The following table compares the temperatures of the three years in which I recorded them:

No.	1871.		1872.		1878.	
	Spring.	Air.	Spring.	Air.	Spring.	Air.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
1	187	55 to 60	186	62	174	39
2	195	55 to 60	188	64	186	39
2a.		55 to 60	182	64	181	39
3	185	55 to 60	162	64	165	39
3a.		55 to 60	190	64	190	39
4	192	55 to 60	192	62	187	39
5	196	55 to 60	194	64	189	39
Cone.	195	55 to 60	190	64	186	39
6	196	55 to 60	184 to 190	64	177	39
7		55 to 60	192 to 195	64	190	39
8	192	55 to 60	188	64	190	39
9	175	55 to 60	171	62	165	39

I am not of the opinion that the temperature of the air has much to do with the variations in temperatures of the springs, although the hygrometric condition of the atmosphere may slightly affect the surface temperatures, especially in very large pools.

In the table above, the differences are probably due mainly to differences in the intensity of activity, and a degree or so may possibly be due to the differences in the thermometers.

THIRD OR FOUNTAIN GROUP.

This is probably the most important group in the Lower Geyser Basin, as it contains more active geysers than any other group, one of them, The Fountain Geyser, being almost equal to the Great Fountain. It also contains the Mud Puffs, one of the most remarkable and beautiful mud basins within the limits of the National Park.

The mound of siliceous deposits on which the Fountain Geyser is situated is conspicuous from most parts of the Basin. The springs on it are Nos. 7 to 15, and of these four are true geysers, while others are spouting springs. Below the geyser mound or plateau is a wide, flat area on which the drainage from the Fountain and the adjacent springs spreads out. There are several large basins on this lower level besides many small springs and steam jets.

The Mud Puffs are on a higher level than the Fountain, from which it is separated by a growth of low, scrubby pines. In this area there are evidences of the former existence of springs and geysers.

Table of Third or Fountain Group.

Number and name.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1. Mud Puffs	40 to 60 feet (?)				Described in full in text following this table.
2	25 feet diameter	162	2.45 p. m.	45	Milky-blue tinted water.
3		196			Large bluish spring, with white and yellowish basin.
3a		79			Red-lined fissure-like spring on water-way from No. 2.
4	About 75 by 100 feet	*120			Green-lined spring, with scalloped border; bubbles in center.
5	16 feet long; 9 feet long at one end, and 5 feet at the other.	198			Spouting and boiling at narrow end.
6	2 by 3 feet	193			Reddish muddy spring water; rises and falls.
7	Spring 4 by 10 feet in basin; 6 by 20 feet.	170			Clear bubbling spring.
8	Basin, 7 by 9 feet; orifice, 4 inches by 1 foot.	190			The basin is composed of beaded silica; spouts a foot or two.
9	3 holes in beaded silica				Water out of sight.
Old Cone Spring	Triangular, 6 feet across the basin.	197			This spring is back of a cone, in which spring is dead.
10. Fountain Geyser	100 by 150 feet	199	3.40 p. m.		For further temperatures see text following table.
11. Jet Geyser	20 feet diameter	195			A very active geyser.
12. Spasm Geyser	12 by 25 feet	†184 ‡176	4 p. m.	41	The spouting orifice is in a gray-edged basin.
13. Clepsydra Geyser	45 feet; 10 feet wide, 3 feet high; orifice, 2 by 3 feet.	192	12 m.	43	Active geyser.
14	8 by 15 feet	179			Greenish-tinted spring, bubbling slightly.
15	2 by 3 feet	193			Water is 5 feet below the surface, in a cavern-like hole, which receives some of the overflow from the Fountain.
Gore Springs	Fissure spring	*a* 188 *b* 177	1 p. m.	44	*a* is a spouter. *b* has two orifices.
	c 18 inches by 1 foot	*c* 195			*c* has clear water; overflow goes to *b*.
	d 2 feet by 18 inches	*d* 190			*d* is a clear, light, yellow-lined hole.
Fitful Geyser *e*		*e* 195			This *e* is at one end of the basin *f*.
	g 10 feet long	*g* 176			*f* is a basin; *g* is greenish basin.
		169 174 183 192			Four small holes between *f* and *g*.
	h 2 by 3 feet	*h* 167			*h* is funnel-shaped below *e* and *f*.
	i hole	*i* 192			*i* is a spouter below *a b*.
16	15 feet long				Two basins of about 5 feet diameter; each receives water from gore springs.
16*a*		191			On fissure with 16; a quiet white-lined spring.
16*b*		198			Spouter below 16 *a*.
17. Back Spring	10 feet diameter (?)		9.40 a. m.	40	Boiling spring; can't reach for temperature.
17*b*	10 feet diameter	§160			Quiet spring, 17; 17 *b* and another hole are all in same basin, which connects with 19.
18	20 feet diameter	*a* 151			Large pool, with two beautiful blue springs and a spouting hole; basin is white, marble-like.
19		105			Circular spring near the end of No. 17.
20	10 feet diameter (?)	85			Merely a basin near 19.

* At edge of spring. † In orifice. ‡ In basin. § At edge.

Table of Third or Fountain Group—Continued.

Number and name.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
21		*a* 179 *b* 174 *c* 174			Basin with three orifices; *a* and *b* are greenish-tinted; 21 is between 22 and 19.
22	Openings, 5 or 6 by 3 feet.	*a* 172 *b* 173 *c* 150			Three openings in yellow deposit.
23	10 by 6 feet	146			Quiet pool, with green lining.
24		150			Quiet green holes.
25	4 by 10 feet	*195			Spouts irregularly a foot or two.
26	100 feet diameter (?)	†169	10.30 a. m.	39	Probably a geyser; has a large pool of greenish-tinted water.
27	All on a long fissure; *f* is 5 by 12 feet; *g* is 10 feet diameter.	*a* 196 *b* 197 *c* 198 *d* 190 *e* 198 *f* 196 *g* 162			*a* is a spouter. *b* is a spouter. *c* bubbles occasionally. *d* is a quiet spring. *e* is a constant boiler. *f* is a violent boiler. *g* is a quiet spring.
27½	2 by 4 feet	198	11 a. m.	42	Between 27 and 28.
28	100 feet long; 30, 50, and 75 feet wide.	†157			
28*a*	4 feet diameter				Spouts a foot or two.
29	12 by 30 feet; spreads out into a pool.	160	1.40 p. m.	45	Cavern-like spring at foot of Fountain plateau.
30	10 feet diameter				Green spring.
31					Stream, jets, and springs not examined.

* When quiet. † At edge.

DESCRIPTION.

No. 1. *Mud Puffs* (Plate VIII).—This remarkable mud caldron has a basin which measures about 40 by 60 feet, with a mud rim on three sides which is from 4 to 5 feet in height. In this basin is a mass of fine, white mud which is in a state of constant agitation. It is like some huge boiling paint-pot or bed of mortar. There are numerous points of ebullition, and the constant boiling has reduced the contents to an intimately mixed mass of siliceous clay. There is a continuous plop-plop of mud, which rises in hemispherical masses, cones, rings, and jets. On the fourth side or south end of the basin the rim is low and forms the edge of a mud flat of pink and red mud, which is cracked, and over which there are some 30 or 40 mud cones, generally of pink and rose colors, although a few are gray. They are from a foot to 2 feet high as a rule, although some are 3 feet. These cones or mud puffs are what have given rise to the name for the caldron. Some are geyseric in action, and send spurts 4 or 5 feet into the air. The mud in them is much thicker than it is in the main basin. There are also several pools of turbid water in this mud flat, and outside of the basin are a couple of mudholes. The red mud cones are seen in the foreground of the illustration (Plate VIII), and back of them the White Mud Basin is shown.

No. 2. Back of the Mud Puffs at a somewhat lower level is an almost circular spring about 25 feet in diameter, with a white rim inclosing rather turbid, milky-blue water with a temperature of 162° F. When examined it was perfectly quiet, but the surrounding deposit indicates that it is subject to periodical overflows. Near it is a small throbbing mud vent which is about 3 inches in diameter. The channel leading

from this spring is lined with very handsome rosetted pebbles of geyserite. Pine cones coated with silica are also seen along its course.

No. 3. This spring is near the foot of the ravine below No. 2, and is a large white and yellowish cavern-like basin in which the water has a bluish tint, which is especially dark over the spring proper, for there is both a pool and a spring in the basin, which is very irregular in shape. The water at the spring has a temperature of 196° F., and a great quantity of steam escapes from it, obscuring the view. No. 3, a, is simply a red-lined fissure in the water-way from No. 2, and the water it contains is largely derived from the latter spring.

No. 4. This is a large spring about 75 by 100 feet, a short distance northwest from the Mud Puffs. It has a green-lined basin and bubbles in the center. The border of the spring is scalloped. The temperature of 125° F. was taken at the edge. Between this spring and the Mud Puffs there are several steaming mudholes.

No. 5. is a very active boiling spring at a little higher level than No. 1. It is a square-cornered hole in laminated geyersite, measuring 16 feet by 9 and 5 feet. The active part is at the narrow end, where there is a constant spouting and boiling. The water here has a temperature of 198° F.

No. 6. is the remaining spring on the upper level. It is a small pulsating spring of reddish, muddy water, with a temperature of 193° F. Between it and No. 5 there is a small hole filled with clear water.

Besides these springs there are several old cones that mark the former sites of springs. In some of these the deposit has a firm, hard, opaline structure.

The springs and geysers from No. 7 to No. 16 are on the main geyser mound, which is almost circular in shape, the drainage radiating in all directions but one, and in that we have the higher level on which the Mud Puffs are located. This mound has been called Fountain Terrace, and on its summit is the Fountain Geyser. It is about 80 feet above the general level. Springs 7, 8, and 9, are back of the Fountain Geyser and are unimportant. Old Cone Spring is merely the remnant of what was once probably a geyser.

No. 10. *Fountain Geyser* (Fig. 2, Plate VII).—The Fountain Geyser consists of a spring and a pool separated only by a narrow constriction. The spring, which is the geyser proper, is about 30 feet in length by 20 in width. It narrows in the direction of the pool and has rather square corners. It is an opening in laminated geyserite on a broad, table-like mound. This appears to have had a flat surface, the edge of which forms a distinct rim or line around the basin, over which, in most places, it projects a few inches. From beneath this rim the sides slope in somewhat rounded masses, which are distinctly seen when the water is low in the basin, and have a little resemblance to a series of cushions around the edge. The rim marks the level at which the water usually stands, and just outside of this, on all sides but one, there is an irregular mound-like mass of beaded geyserite which has been built up by the evaporation of the water that falls during the eruptions. It is from 2 to 4 feet in height. In one end of this basin is a cavern-like hole, which is the true geyser, and over which the water is of a beautiful blue tint, like the color of blue-bottle glass.

The pool of the Fountain, a portion of which is shown in the foreground of the illustration (Plate VII, fig. 2), is about 120 feet in length and 100 feet in width; an immense quantity of steam rises from it, which obscures the view. It is generally shallow and without a marked rim. It has two basins, or bowls, however, that are deep. The largest

MUD PUFFS FOUNTAIN GROUP LOWER FIRE HOLE BASIN

of these is about 50 feet in diameter, and cavern-like, with greenish-tinted water. The small basin or bowl measures about 15 feet by 6 or 8 feet.

The following are the temperatures that were taken this year (1878):

Date.	Temperature.	Condition of basins, &c.
	° F.	
October 1	199	Basin is full 10 minutes before the eruption.
2	200	Basin is full 1 minute before the eruption.
2	174	About an hour after the eruption and the water is perfectly quiet.

The temperature of the water in the pool was 160° F.

The eruptions witnessed by us are not known to be consecutive. The first one occurred on October 1, and lasted 17 minutes. The spouting occurs from the crater-like hole, and preceding the action the water was boiling rather vigorously, somewhat like the Giantess in the Upper Basin. A great mass of water was pushed out tumultuously to an average height of about 10 feet, and through this jets were projected which reached a maximum height of 50 feet. There appeared to be several centers from which the steam escaped, and the water was churned and dashed about until it was a white mass. There were periods of increased activity and cessation. About half an hour before the eruption the water did not quite fill the basin, but immediately after it was over it was level with the top, eight minutes later it was 6 inches below the rim. After none of the eruptions was the basin entirely empty. Professor Comstock describes the eruptions seen by him in 1873 as follows:

* * * The water in No. 5 [Fountain] which had previously been quiet and not entirely filled, rose suddenly until the bowl was ready to overflow, when a large amount was elevated to a height varying from 6 to 10 feet, in a column of nearly equal diameter. The action began at 4.40 p. m. (August 23), and the eruption did not cease wholly until 5.40 p. m. Occasionally very sudden impulses would carry smaller but quite large columns 25 and 30 feet into the air. Sometimes the whole would gradually die down, and more than once when I thought that the ejection had ended, a vigorous throb would violently throw the water and vapor to its greatest height. The rushing noise produced by the escaping liquid was very loud, and a subsequent eruption, which occurred from 7.30 a. m. to 8.30 a. m., on the following morning, was distinctly audible at our camp near White Dome Geyser, more than a mile distant. At the close of the first eruption the water receded in the bowl, so that we could look down many feet into the large open pit which was thus formed. * * * A third eruption of this geyser (apparently) began at 1.20 p. m., August 24, the duration of which was not determined. *

Captain Ludlow witnessed an eruption of the Fountain in 1875, and describes it as follows:

The water, of a deep azure hue and a surprising clearness, was rising gradually but constantly to the level of its scalloped and ornamented rim, constantly becoming hotter and hotter, with bubbles of steam escaping more and more rapidly. Ebullition began near the middle, and the geyser finally commenced to spout, throwing the water about in all directions and to heights varying from 10 to 50 feet. The display continued for over an hour, and we left it playing, but with gradually diminishing force. Meanwhile other smaller geysers in the vicinity played from time to time, all apparently independent of each other.†

* Report of Reconnaissance of Northwest Wyoming in 1873 by Capt. W. A. Jones, pp. 245, 6.

† Reconnaissance from Carroll, Mont., to Yellowstone National Park in 1875, by Capt. W. Ludlow, p. 25.

The following are the observations of Professor Comstock and myself:

Observer.	Date.	Eruption began.	Duration.
		h. m.	*Minutes.*
Comstock	Aug. 23, 1873	4.40 p. m.	60
Do	Aug. 24, 1873	7.30 a. m.	60
Do	Aug. 24, 1873	1.20 p. m.	.....
Peale	Oct. 1, 1878	3.50 p. m.	17
Do	Oct. 2, 1878	12.11½ p. m.	19
Do	Oct. 5, 1878	3.20 p. m.	.....

These obeservations are of course too limited to base any law upon them but they may be of use in the future, and they are therefore recorded.

It appears probable that there are about six eruptions in the twenty-four hours, although the geyser has not been studied constantly nor closely enough yet to determine this fact. In 1871 we were of the opinion that they occurred every twelve hours, but even in that year we were not sure that we saw all the consecutive eruptions. The duration appears to be very variable. In 1871 it is was noted as 45 minutes; in 1872, 30 minutes; in 1872, 60 minutes; in 1875, over an hour; and in my observations of 1878 only 17 to 19 minutes. In 1871 the lowered state of the water, until just before the eruption, was also noticed, and the time of the preparatory bubbling was noted as about an hour. We could not devote time enough to determine this in 1878. The following note is from Col. P. W. Norris's report for 1881, page 57:†

Fountain.—Unusually had an eruption each forenoon, those observed being of from 10 to 15 minutes' duration, with water column from 60 to 90 feet high, and very spreading.

No. 11. *Jet Geyser.*—This geyser was named in 1872, but not described, and in 1873 Professor Comstock called it Impulsive Geyser. It is a short distance south of the Fountain, and has a beaded basin 20 feet in diameter, which slopes to a funnel which has an orifice at the bottom only about a foot wide. When in action the basin fills, and the water is thrown out in all directions, with every now and then a perpendicular jet which reaches 10 or 15 feet above the basin. The water is fearfully agitated, and there is a throbbing noise under the surface. The wind blows the column sideways, but at intervals a jet appears to be projected with extreme violence. After the eruption is over, the water sinks out of sight. Professor Comstock describes the eruption witnessed by him as follows:

At first it sputtered sullenly, and the water was thrown upward but a little distance, but gradually the action became more rapid and violent, a small jet occasionally rising with considerable force to a height of 15 feet. The contents of the bowl were thoroughly agitated, but the greatest activity occurred in the center, the jet being thrown, as it were, through the middle of the main mass ejected, which may be likened to a fountain.*

The data obtained are not sufficient to determine the period of this geyser, but it is probably frequent in its action. On October 1 I saw one eruption that lasted 25 minutes. On the 2d an eruption lasting 19 minutes was observed, and after it ended the water was sucked into the

* Report of Reconnaissance of Northwestern Wyoming in 1873, by Capt. W. A. Jones, p. 244.

† In Colonel Gregory's report to General Sheridan (in Report of Expedition through the Big Horn Mountains, Yellowstone National Park, etc., in 1881; Washington, 1882) the Fountain is said to have played August 24, 1881, the action lasting 45 minutes.

tube. In 1873 the eruption witnessed by Professor Comstock lasted two hours. The following are the temperatures I obtained:

Date.	Time.	Temperature.	Remarks.
		°F.	
Oct. 1.....	11.22 a. m.	198	Water is rising and bubbling, with occasional steam bulges and spurts. This is 57 minutes before the eruption.
1.....	12.05 p. m.	195	Water still rising.
1.....	1.36 p. m.	197	Water is rising.

The first eruption ended 5 minutes after an eruption of the Fountain began, which occurred 20 minutes after the Jet began. When the second one was observed, the Fountain began nearly 27 minutes before the Jet began to spout, and it ended before the eruption of the Jet ceased. There is therefore, probably, no connection between the two geysers.

No. 12 was spouting continuously during the first eruption of the Jet, and during the second it was quiet; and in the eruptions noted by Professor Comstock in 1873 the two ceased action almost simultaneously, so that between these two also there is a lack of sympathy, although Professor Bradley in 1872 thought there was sympathy between their action and the Fountain. He says:

I stood one morning upon the mound of Fountain Geyser, in the Lower Basin, whose pool was filled to overflowing, and was watching a vehement steam jet a hundred yards away, on the lower slopes of the terrace. Suddenly this ceased, and at the same instant Fountain commenced playing. * * * This continued for about 30 minutes, and then ceased rather abruptly; as suddenly the steam jet commenced again. About 20 minutes later it ceased again, and a small pool [Jet Geyser] a few yards from Fountain, which had been empty before the latter's eruption, but partially filled by its overflow, immediately began to boil and spit water from 5 to 10 feet high, and continued intermittently for a half hour or more. During its periods of moderate boiling the steam jet opened again, but ceased when the boiling became more violent.*

This apparent sympathetic action was only a coincidence, as more extended observations have shown.

No. 12. *Spasm Geyser.*—This, which is rather a spouting spring than a geyser, was named by Professor Comstock in 1873. It has a yellow, rather shallow, basin 25 feet long by 12 feet wide. It has a gray edge, and is handsomely ornamented on the edge and in the basin. The water is spurted from a hole at one end and rarely attains a height over 2 or 3 feet. When seen on the 1st of October it was spurting continuously from the time we arrived, about two o'clock, until we left, at half-past four. On the 2d it was in action part of the time we were near it, and part of the time it was quiet. The temperature in the basin was 176° F., and in the spouting hole 184° F. It receives the overflow from the Jet Geyser.

No. 13. *Clepsydra Geyser.*—This geyser was named by Professor Comstock in 1873 from its fancied regularity. He says:

Like the ancient water-clock of that name, it marks the passage of time by the discharge of water.†

It has a central cone which is 15 feet in length, 10 feet in width, and 3 feet in height. In this cone, which is beautifully beaded, the orifice is about 2 by 3 feet. To the right of it, *i. e.*, in the direction of the Fountain, is a large yellow-lined orifice, which has an opening into the main cone,

* Report U. S. Geol. Surv. for 1872, p. 235.

† Report of Reconnaissance in Northwestern Wyoming in 1873, by Capt. W. A. Jones, p. 245.

and when the latter is in operation the water spurts from it into this orifice and the overflow pours from it into a depressed basin in old gray geyserite, just to the east close to it. At the west end, at the foot of the cone, is a white-lined, shallow basin, in which the water has a depth of an inch. In this basin, near the cone, is a bowl measuring 3 by 4 feet, from which the water is continuously spouting and bulging, sometimes reaching a height of 5 or 6 feet. This bowl has periods of quiescence which appear to be independent of those in the main geyser, spouting sometimes when the latter is quiet and sometimes when it is in action. The temperature in this pool is 192° F. The entire length of the geyser, including the pool and the depressed hole, is 45 feet. The main cone spouts in a spasmodic manner with vigorous spurts which reach a height of 10 to 25 feet, and even 30 feet at times. On October 1 it was in action from two o'clock until half-past four. How long before this it had been spouting I cannot tell, nor how long it lasted after I left. At 11.30 a. m. on the 2d it was spouting as when I left it the previous evening, and it was still in action when I left, at 1.40 p. m. In six minutes there were 38 spurts, which is an average of one about every 10 seconds. The intervals were from 3 to 26 seconds, the longer intervals being at about every seventh one. Professor Comstock gives the interval as about every 3 minutes. The geyser was in action constantly during his visit to it (a period of about two hours and a half). On October 5, when I noted an eruption of the Fountain, this geyser was perfectly quiet, so that it is not a constant geyser, as Professor Comstock supposed.

No. 14 is a bubbling pool between the Clepsydra and the Gore Springs. No. 15 is an unimportant hole which receives some of the overflow from the Fountain.

Gore Springs.—I have given this name to a group of springs near the edge of the terrace, which are characterized by an abundant deposit of ferric oxide, which gives a gory appearance to the surroundings. There are altogether about a dozen springs and pools. To one of them (*e*) Professor Comstock has given the name of Fitful Geyser, although it spouts only a foot or two. It has intervals of quiet, the duration of which was not determined. Several of the springs besides are spurters, but none throw the water to a height of more than 2 feet.

No. 16. This is a spouting spring on the line of a fissure in the mound near the edge, just below the Gore Springs; *a* and *b* are on the same fissure.

This completes the springs that are on the Fountain terrace, or plateau. At the foot of it, south of No. 13, is No. 29, a large cavern-like spring with a pool. No. 30 is here also, and beyond this is a wide flat with small springs and numerous steam vents. Following around the edge of the terrace to the west and northward we find the remaining springs of the group (Nos. 17–28). Several of these are very large, and a number are spouters of considerable size, and one or two are probably geysers of considerable power, although they were not seen in action.

Nos. 17 (Back spring), 17*b*, and No. 19 are three openings or bowls in a large, somewhat irregular basin; No. 17 is a boiling spring and 17*b* is quiet; No. 19 receives overflow from them. Outside of the bowls the basin is shallow. It was difficult to obtain the temperatures in these bowls as they were some distance from the rim of the basin.

No. 18 is a handsome, large pool or basin with two bowls, each about 20 feet in diameter, with beautiful blue-tinted water. The basin is white and marble-like with a yellow ornamented rim of fungoid-like mosses. At one side there is a spouting hole, from which the water is spurted occasionally. This hole is about 6 inches in diameter. At

times the water of No. 18 evidently connects with that of No. 17. No. 18*a* is one of the two large cavern-like bowls in the basin, and is the only one in which I could obtain the temperature. Back of No. 18 are a number of sizzling holes.

Nos. 20–23 are back of No. 17 and are sufficiently described in the table.

Nos. 24 and 25 are back of No. 18. They are really within the limits of one basin when full of water. No. 25 spouts irregularly to the height of a foot or two.

No. 26. This is a large pool, probably a geyser, north of No. 18. It was estimated to be about 100 feet in diameter. It has a gray basin, in which there is a fissure over which the water has a greenish hue. The temperature (169° F.) was taken at the edge of the basin.

No. 27 includes a number of springs on the line of a fissure. They represent only a few of the springs on the flat. The surface is perforated with steam holes and bubbling and spouting springs. No. 27½ is one of those nearest to No. 28. No. 31 is in the opposite direction.

No. 28. This one of the handsomest springs on the lower level. It is somewhat irregular in shape, 100 feet in length by 30, 50, and 75 feet in width, and has a white, scalloped, overhanging edge. As far as seen it is a quiet spring, no boiling centers having been noted. It receives some of its water from the subgroup on the Fountain terrace. It has a beautiful sky-blue hue over the deeper parts of the pool. The temperature (157° F.) was taken on the edge.

No. 28*a* is a circular spring, 4 feet in diameter, with a grayish-white basin and yellow and white rim. From the center of this basin a small jet of water is thrown a couple of feet into the air.

The map made in 1871 shows only seventeen springs in this group, and of these No. 4 is the only one in which I can compare the temperature. In 1871 it had a temperature of 140° F., and in 1878, 120° F. On the terrace of the Fountain the springs are so crowded that is difficult to show them on the map, and in the flat below only the most important are given on the accompanying map.

FOURTH OR FISSURE GROUP.

This group might well have been named the Lake Group, for it is characterized by hot lakes and ponds. A large quantity of water goes from the springs and ponds, flowing over steps and terraces in an intricate network of streams. Some of the latter are wide and deep, and are filled with a luxuriant vegetation. Below the lakes and terraces the water spreads out on the flat and unites with the drainage from the springs about the White Dome Geyser. In this area there are large numbers of dead trees that have been killed by the flow of hot water. This group is interesting also as containing a few springs in which sulphur is deposited, which is rarely found to be the case in the Lower and Upper Geyser Basins. The springs are situated mainly on the sides of the ravine or valley in which the lower lake is situated, and at the east end of the main or upper lake. There are four lakes, the largest of which is about 1,000 feet long and 800 feet wide. There are two principal geysers, although the height to which they throw the water is not great. The following table contains the principal springs of the group:

Table of Fourth or Fissure Group.

Name or number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1		147			These are on the south side of the marsh that is on the south side of the lakes. There are others in the marsh that were not taken.
2		170			
3		164			
4		170			
5		165			
6	10 by 15 feet	201			Beautiful spring, with dark, green-tinted water.
7	Cone in which the water is 2 feet below top of the spring.	163			This cone is probably an old geyser. It is lined with globular masses.
8	5 by 10 feet; water in basin 2 by 3 feet, and 4 feet below the top.	198			The walls are vertical, and the water bulges from an orifice of about a foot in diameter.
9. Bead Geyser		197			Beaded Geyser, with other springs back of it.
10	10 feet diameter	166			Quiet; white-lined spring.
11	Basin 5 feet in diameter; orifice 1 by 2 feet.	198			White-beaded flat basin. This is a geyser that spouts at times.
12. Pink Cone Geyser	Cone 18 inches high, with orifice 2 feet in diameter.	199			Beautiful pink cone, with a second cone close by; also, a small pool near it.
13	30 feet long; average width is 7 feet; greatest width is 10 feet.	130	10.15 a. m.	47	Leathery-lined spring.
14		126			Red springs, in which there is a strong odor of sulphureted hydrogen gas.
15	8 by 10 feet long	*197			Gray-lined spring that gives off bubbles of sulphureted hydrogen gas.
16	30 by 35 feet; inside basin is about 15 feet diameter.	151			Beautiful bluish-green tinted spring in sulphur-lined basin.
17	6 feet diameter; basin below is 5 by 15 feet.	159			Lemon-yellow, funnel-shaped spring, with iron-lined basin below; gives off hydrogen sulphureted gas.
18	2 by 3 feet	185			In hard geyserite; bulges a little and gives off hydrogen sulphureted gas. There are other similar springs near this one.
19	Small	148	10.45 a. m.	43	Two outlets on hard deposits.
20	Small	185			
21	7 feet diameter	197			Brown-lined basin in hard geyserite; boils vigorously, and has considerable overflow.
22	3 feet by 18 inches; water is 2 feet below top.	199			Fissure in hard geyserite.
23	Small hole	171			
24		†151 ‡186			Rather quiet, brown-lined pool, with a hole at one end just outside of the pool.
25					A red pool, receiving water from 24, which sinks in a shallow pool still further below.
26	2½ by 5 feet	177			Fissure-like near the edge of the lake north of the Steady Geyser.
Steady Geyser		§195			A rather powerful geyser.
27		174			Back of the Steady Geyser, and receives water from the springs above.
28		198	11.45 a. m.	52	Small bubbler.
29	10 by 15 feet	144			Pool in the water-way from Young Hopeful Geyser.
30		169			White fissure.
31	8 by 10 feet	199			Blackish boiling spring, with pool below.
32		197			Boiling spring.
33		168			Black-lined pool.

* At one end. † Pool. ‡ In hole. § In pool of geyser.

Table of Fourth or Fissure Group—Continued.

Name or number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
Young Hopeful Geyser.		175	12 m	52	Spouting continuously when notes were taken.
34. Gray Bulger		197			Bulges through a hole in gray geyserite.
35		81			Quiet pool.
36		196			Boiling spring.
37		188			Boiling spring.
38		159			Quiet.
39	10 feet diameter	169			
40		192			Boiling spring.
41	7 feet diameter	166			Black-lined funnel-shaped spring on opposite side of lake from Young Hopeful.
42	8 feet diameter	170			Quiet, black spring.
43		130			Red-lined spring in the grass. There are other small holes near this.
44	12 feet diameter	140	1.15 p. m.	48	Small greenish spring.
45	4 by 8 feet				Turbid boiling spring.
46		82			Quiet pool.
47	20 feet diameter	160			Sulphur-lined spring.
48	25 feet diameter	186			Pink-beaded basin: yellow-beaded one.
49	2 feet triangular; sides to orifice.	185			
50	3 feet diameter	187			White and yellow-edged spring.
51	5 by 6 feet	*a* 196 *d* 186			White basin with two openings.

DESCRIPTION.

Springs Nos. 1 to 5 are on the south side of the ravine, and are the first met with on coming from the White Dome. They are at the foot of the hills in very marshy ground. Besides these there are others, as the map indicates, but it was impossible to reach them on account of the treacherous nature of the soil.

Nos. 6 to 11 form a cluster on the opposite or north side of the valley or ravine. They are situated on a mound of hard deposit, on which No. 6 is the central and most important spring.

No. 6 has a beautiful basin, 10 by 15 feet, of irregular shape, in which the water has a dark-green tint. The rim extends over the spring in great scallops, on which the water stands to a depth of half an inch or so. This is white and yellow, and forms an outer basin 3 to 4 inches above the general level outside. The spring constantly bubbles and boils at one end and sends the water in waves over the scalloped rim. The temperature was 201° F.

No. 9. *Bead Geyser* is a spouting geyser with a beautifully-beaded tube. No data were obtained as to the height, duration, or interval, as our stay was too short to allow of much time being devoted to it.

No. 11 is a spouting spring on the water-way from No. 6. It has a beaded flat basin.

No. 12. *Pink Cone Geyser.*—This is a beautiful rose-tinted cone 18 inches in height and about 5 feet in diameter. The orifice is round, measuring 2 feet in diameter. It is beautifully beaded, and the cauliflower-like formation is strong evidence that it has periods of eruption. It has never been seen in action, and therefore nothing is known as to its in-

terval nor height of its column. Balls of geyserite are found in a fissure close by, and there is a second smaller cone and a pool.

Springs Nos. 13 to 18 are situated on a flat north of the main Hot Lake. Eastward from this flat there extends a valley which has a deposit of broken fragments of geyserite, which is overgrown with pines. A ridge separates this valley from the ravine in which the springs already described are situated, and another ridge separates the western end from the Mud Puffs. Most of the springs in this cluster have sulphur in their basins.

No. 13 is a leathery-lined spring or pool 30 by 10 feet. In the grass above it are several red springs, the principal one of which (No. 14) has two bubbling basins which give off sulphureted hydrogen, and in which the water has a temperature of 127° F. Still farther above is No. 15, a gray-lined sulphur spring with a high temperature (197° F.). Between this spring and the lake are sulphur-coated spots.

No. 16 is a handsome spring of bluish-green tinted water in a sulphur-lined basin of 15 feet diameter. There is an outer basin which measures 30 by 35 feet, and beyond this the water reaches to a distance of 6 or 8 feet on a brown-coated area. The spring has a white rim, and the outlet is coated with iron oxide. Sulphureted hydrogen is given off, and the area outside the spring has sulphur holes in it. The water bubbles slightly and has a temperature of 151° F.

In the grass surrounding these springs there are others, and in the timber back of them are several with hard, mound-like basins.

The springs next described are east of the Steady Geyser, and are included under Nos. 19 to 27. Nos. 19 and 20 are not shown on the map. They are two small hot streams coming out of a hard deposit without basins, and flowing into a red basin in marshy ground The rest of these springs are sufficiently described in the table.

Steady Geyser.—This geyser was named in 1871 from the constant action of the column. It is close to the edge of the small lake which is just east of the main Hot Lake. The water is projected with rather steady force in an oblique direction from the side of an irregular mass of deposit that forms a mound a couple of feet in height. The deposits are not remarkable either for beauty or quantity. Most of the water falls into the small Hot Lake. There is no well-defined column of water, but an irregular, splashing mass that appears to be pushed out with great violence. A great quantity of steam accompanies it, and the extreme height attained is not over 30 feet. Usually the height is from 10 to 15 feet. It was impossible to take the temperature of the water, but in the pool just south of the geyser a temperature of 195° F.was obtained. In the lake the temperature was 142° F. The latter drains into the large lake. Just south of the Steady Geyser is a small spouter which appears to be in constant action.

Back of the geyser are a number of pools and springs, some of which are on the drainage lines that come from the lake near which Young Hopeful Geyser is located. These springs, as well as those near the lake just south of the Steady Geyser, are sufficiently described in the table.

Young Hopeful Geyser.—This small geyser was so named by Professor Bradley in 1872, and appears to be a constantly acting geyser. It is near the edge of the Upper Lake, and has a flat basin, lined with nodular masses of deposit, which is brilliantly colored, orange, yellow, and cream colors being mixed with the white. The central orifice is about 2 by 3 feet. The temperature is 175° F. The spouting is rather irregular. When I saw it it appeared to be continuous. Professor Bradley

says it spurts from 2 to 10 feet high for from 65 to 80 seconds, with quiet intervals of about the same length. Professor Comstock, who saw it in 1873, says it spouted irregularly, with active and quiescent epochs of one or two minutes' duration, and gives the height as 3 to nearly 10 feet. I estimated the height as 5, 10, and 15 feet. It is doubtful if it ever exceeds 20 feet. Beyond the geyser is a red pool, and back of it a small geyser which I have named.

No. 34. *Gray Bulger.*—It spurts to the height of a few inches only at intervals of 45 to 60 seconds, the spoutings or bulgings lasting from 30 to 40 seconds.

At the east end of the lake is a collection of springs (Nos. 35 to 39), which do not merit specific description. Several of them are boiling springs. Beyond them is a brownish laminated rock which appears to be an old spring deposit.

On the north side of the lake, opposite Young Hopeful, are several unimportant springs (Nos. 41 to 43), and a number of holes in the grass.

Returning now to the Lower Lake, we find in the timber on the edge of the ravine or valley south of the Steady Geyser a circular, green-lined spring (No. 44), and still farther west a collection of sulphur springs (Nos. 45 to 47). The sandstone deposits near this latter cluster are honeycombed and riddled like the sandstones near some of the springs in the Shoshone Basin. Professor Bradley found similar perforated sandstones near the Architectural Geyser or Great Fountain in the Fifth Group just South of the locality in which these springs occur. He thinks that it represents on a small scale the process by which the basins of the springs are formed.*

Crossing now to the north side of the valley below the terraces, and skirting the hills on that side as we go to the westward and northward towards the Fountain Group, we find four interesting springs (Nos. 48 to 51), which I have included in this group.

No. 48 is a pink-beaded basin 25 feet in diameter on the outside and 15 feet in the inner basin. The water was 10 feet below the top, and had a temperature of 186° F. The basin and throat of this geyser are beautifully frosted and beaded. The orifice is triangular, measuring 3 feet on the sides. The height to which it spouts is 15 or 20 feet, as observed on the one occasion on which it was seen in action. Farther along is No. 49, a cone with a triangular orifice. Northwest of the latter is No. 50, a white mound spring with yellow edge; steam escapes with a thumping noise.

No. 51 is a beautiful white basin (5 by 6 feet) with two openings, one 18 inches in diameter and the other 8. The latter (*a*) bulges, and has a temperature of 196° F., while the former is 186° F. The water rises and falls in the basin in pulsations.

FIFTH OR WHITE DOME GROUP.

South of the springs last described, under the fourth group, is a wide, flat area, partly marshy and covered with broken geyserite, over which an intricate network of small streams from the Fissure Group interlace with others coming from the south, and which have their origin in a group of springs surrounding a cone that forms a conspicuous object in the landscape. This cone was named the White Dome Geyser in 1871, and from it the group of springs is named. South of it the valley narrows into a ravine, which is lined with hot springs, which I have in-

* See Report of U. S. Geol. Survey for 1872, p. 235.

cluded in the same group. The stream from this ravine, instead of flowing past the White Dome to join the stream from the Fissure Group, as was formerly supposed and shown on all previous maps, turns to the westward in the neighborhood of the Great Fountain, and disappears in the timber, to reappear on the banks of the Fire Hole, opposite the marshy lakes, with a diminished supply of water, most of it having been lost in marshes in the passage through the woods. This has been one of the reasons why the stream has not been recognized before. Mr. Mushbach followed and discovered this fact this year, although it had been suspected by Mr. Holmes. In this group we have the largest and most active geyser in the Lower Geyser Basin, beside the only true geyser cone or mound of any height that at all resembles those of the Upper Basin.

The springs extend up the ravine in small groups, somewhat isolated, to a distance of about 1,500 feet above the Great Fountain. There are two falls of 7 feet and 10 feet, respectively, on the stream. Below the White Dome, on the plain, there are a number of trees that have been killed by the action of the hot water, and their bases are coated with a white deposit of silica, which has been carried up from the base of the tree in the water by capillary action and left by the evaporation of the water, and not, as Professor Comstock supposes, by deeper floods of siliceous water.

According to my usual plan, I now give the springs of the group. The temperatures of about 62 springs were taken, although there are perhaps more than that number of springs, all not being enumerated:

Table of Fifth or White Dome Group.

Name and number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
*1 *a*		166	10.15 a. m.	43	
b		172			
c		175			
d		152			
e		199½			Bubbler.
f		175			
g		199			Near this are two holes.
h		160			
i		163			
k	2 feet diameter	130			Small red-lined holes.
l		128			
m		165			
n		137			
o		163			
p		157			
q		182			White spring.
r		187			
		128			
s		196			Constant bubbler.
t		185			Gray fissure.
u		180			
v	20 feet diameter	150			Gray spring.
2 *a*	Cones	196			There are other openings near these, but water is down out of sight.
b	Basin 7 feet diameter	196			
3 *a*		200¾			A collection of holes in surface.
b		201			
c		190			
Great Fountain Geyser.		199			Basin was not quite full when the temperature was taken.
4	8 by 18 feet	197	1.20 p. m.	.47	Long, irregular-shaped spring.
5	10 by 12 feet	Not taken			Yellow-rimmed spouting spring, fissure-like, with two outlets.

* This group of springs (1 *a* to *v*) is on a broad, flat space below the White Dome Geyser.

Table of Fifth or White Dome Group—Continued.

Name and number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
Beauty		194			Large, beautiful, blue-tinted spring.
6	8 by 12 feet	201			Oval spring on a high mound or terrace.
7 *a*	8 feet diameter	162	2 p. m.	50	Beaded geyserr like funnel.
b	Basin 12 by 10 feet	162			*b* and *c* are in the same basin; *b* is green-lined and *c* is a red pool.
c		145			
8 *d*	4 by 12 feet	160			Small, gray spring near the creek.
e	8 feet long	199			Violent bulger.
f		174			Gray spring.
9	8 by 18 feet	178	2.30 p. m.	49	Diamond-shaped, green-tinted pool.
10	20 feet by 30 feet	*182 †199			Greenish cavern-like spring, with a white yellow-lined border; at one end is a black boilinghole.
11	9 feet diameter	181			Nearly circular gray-lined spring.
12		146			Large red and greenish brown leathery-lined spring.
13	6 by 4 feet				
14	5 by 10 feet	168	3 p. m.	45	Quiet white basin with sloping sides.
15	2 by 2½ feet	176			White-edged hole, bubbling slightly.
16		185			Bubbler.
17	Cone 6 inches high	198			Spouts at times.
18		156			On the edge of the river.
19	15 feet diameter	182			A beautiful greenish spring.
20		199			Bulger.
21		163			Greenish spring with sloping basin.
22		185			Has two white openings.
23		181			White at one end, red at other.
24	12 by 25 feet	182	3.30 p. m.	45	A gray-lined spring into which pieces of geyserite have fallen.
25	5 by 2 feet	172			
26	3 by 8 feet	171			Much like No. 25. Between 26 and 27 is a hole.
27	20 feet long	201			Large gray-lined almost black spring, with three centers of ebullition and a large overflow.
28	2 feet diameter	182			Hole in the grass.
29	1 by 3 feet	196			Fissure-like hole. Near this is another 4 feet in diameter.
30		189			Besides this there are two; the spring unimportant. They are above a small meadow. This one is a bulger.
31		157			Large, irregular, green-lined springs, with white bordered outlet.
32		176			This is a small, gray-lined hole, without an outlet, just above No. 31.
33		162			This spring gushes out of the side of the hill in black deposit about 30 feet above the creek level.
34		184			Clear spring on the bank of the river. There are a number of dead pools in the grass near by.
35	40 feet diameter	‡153			Large brownish-lined spring in the timber east of the White Dome.

*In pool. †In boiling center. ‡On the edge of the spring.

DESCRIPTION.

No. 1 includes a lot of small springs, mostly round and flat, without marked rims. There are also pools of standing water, with red linings. *a* is a thumping spring. Temperatures in this cluster in 1871 were 162° F., 175° F., 162° F., 153° F. Between this cluster and the White Dome are two red-lined springs at the edge of the mound of deposit that surrounds the White Dome, and on the platform of the latter, principally on the northwest side, are a number of holes and steam vents.

White Dome Geyser.—(Plate IX.) This rather dilapidated cone represents the condition of old age in a geyser, its deposits being soft and crumbling, evidently decaying. It is about 25 feet in height, resting on a platform of deposit. Steam escapes from the sides and from the orifice on top. It spouts irregularly about 5 or 6 feet, occasionally reaching 10 or 12 feet. There is very little water ejected, steam mingled with spray predominating. The geyser is evidently in a state of decay, and the deposits are dingy-gray in color. An old channel shows that once it was a powerful geyser. Steam escapes with gentle force almost constantly. No temperature was obtained, as the water was too far below the top to be readily measured. Professor Comstock gives the following description of the deposits of the Dome:

> The material of the mound at this point is a very compact, flinty variety of geyserite, arranged irregularly in plates, with a clear opal appearing in spots. The exterior is covered with a dark-brown growth of a scummy substance, which turns black upon drying, and a perceptible pink tinge, with a few touches of green, are found beneath and in patches. The recent mechanical deposits about the mouth of the chimney are compactly granular, breaking readily into coarse, uneven joints along no particular lines. The surface contour is irregular, and the whole, when wet, has very much the appearance of a mass of white commercial sponge of a mixed variety, *i. e.*, an average mass with frequent spots of a very fine-pored variety. In an ordinary light, small pieces sometimes have a dingy aspect, much like the color of coarse granular salt recently removed from a saturated greasy brine, but this changes to an extremely delicate pinkish hue in the full play of the sunlight.*

No. 2 marks the site of several cones and springs on the platform a little east of south from the "White Dome." The water in the cones was below the surface when examined. One of them spurts water and steam in a jet to the height of 3 or 4 feet. One of the springs (*b*) has a basin 7 feet in diameter, in which, 2 feet below the surface, at the bottom of a globular-edged cavity, there is an orifice a foot in diameter. This is orange-colored, and from it the water comes in bulges, with a temperature of 196° F. The surface of the platform in several places near these springhs as caved in.

No. 3 is a collection of holes in the surface west of the Great Fountain, with very high temperatures (200¼–201° F.).

Great Fountain or Architectural Geyser.—(Plates X and XI.) This geyser was named Architectural in 1871 and renamed the Great Fountain in 1872, which is by far the preferable name, and the one that will probably be retained. It is probably the unknown geyser of Professor Comstock (see p. 248 of his report). It is a bowl or basin on a platform of geyserite, which is composed of beautifully ornamented geyserite, well shown in Plate XI. The following description by Mr. W. H. Holmes is taken from my report for 1872 (p. 144):

> During our somewhat protracted stay in the lower basin I found time to observe pretty carefully all the geysers of any considerable importance. Among the six or eight which throw columns of water to the height, say, of 30 feet, there is only one that possesses the dignity and grandeur of the great geysers of the Upper Basin. Although,

* Report of Reconnaissance of Northwestern Wyoning in 1873, p. 247.

NEAR VIEW OF WHITE DOME. LOWER FIRE HOLE BASIN.

DISTANT VIEW OF GREAT FOUNTAIN & WHITE DOME LOWER FIRE HOLE BASIN.

in some respects, it is much inferior to its more popular rivals, in others it is certainly superior. In approaching the crater of this geyser the observer is not at first impressed with its importance, as the outer rim of the basin, or rather table—in the center of which the fissure is situated—is raised but two or three feet above the general level. This elevated part I should estimate to be upwards of 120 feet in diameter, and, with the exception of the crater, it is built up nearly to a level with the border. The surface, formed entirely of siliceous deposit, is diversified by an infinite number of forms and colors. The depressed parts in some places are so level and white and hard that a name could be engraved as easily and as well as upon the bark of a beech tree. In others there are most exquisitely modeled basins and pockets, with ornamented rims, and filled with perfectly transparent water, through which thousands of white pebbles of geyserite could be seen lying in the white, velvety bottoms. Rising above the general level are innumerable little masses and nodes of cauliflower-like and beaded silica, standing out of the shallow water like so many islands. Those near the crater swell into very large, rounded masses. The whole surface is so solid that I walked, by stepping from one elevation to another, up to the very brink of the fissure, where I looked down with no little apprehension into the seething caldron, where, 12 or 15 feet below, was a mass of dark-green water in a state of constant agitation, threatening an eruption. The crater is about 10 feet in diameter, lined with an irregular coating of beaded silica. The water soon began to rise, plunging from side to side in great surges, sending up masses of steam and emitting angry, rumbling sounds. This demonstration caused a precipitate retreat on my part to the border of the basin, thinking that I could appreciate the beauties of a scalding shower-bath better from that point of view.

An irregular mass of water was thrown into the air in the utmost confusion, spreading out at every angle and whirling in every direction, some jets rising vertically to the height of 60 or 80 feet, then separating into large glistening drops and falling back into the whirling mass of water and steam; others shooting at an angle of 45° and falling upon the islands and pools 30 or 40 feet from the base. The eruptive force, for a moment, dies away and the water sinks back into the tube. Then, with another tremendous effort, a second body of water is driven into the air, but with a motion so much more simple than before that the whole mass assumes a more regular form and is like a great fountain with a thousand jets, describing curves almost equal on all sides and forming a symmetrical whole more varied and more grand than any similar work by man. The intermittent action continues for nearly an hour, but is so constantly changing that at no two moments during that time are the forms or movements the same. The eruptions are repeated at irregular intervals of a few hours, and are not known to vary essentially from the manner of action here described; yet I have good reason to believe that at certain times there is a much greater exhibition of power. It must be borne in mind that all the elevations, such as the tubes, rims, and mounds about the crater of a geyser, are built by the evaporation of the water, and the portion of surface covered by the beaded silica indicates precisely the area over which the erupted water falls. In no case did I observe the water fall outside of a circle of 60 feet in diameter, and the additional force necessary to scatter it over twice that amount of surface must produce a display truly magnificent. That this display actually occurs is attested by one of our mountaineers, and almost demonstrated by the extent of the beaded surface. During the earlier part of the eruption a considerable quantity of water flows over the rim and down the sides, where it has formed a series of basins somewhat similar in form and color to those at the springs on Gardiner's River. Falling from one to another of these, it passes off down the slope and joins a large stream of hot water which issues from a steady spring not far away.

Plate XI *a* shows some of the ornamental forms. The exact height of the column has never been measured, nor has the interval been accurately determined, because the geyser is quite a long distance from the camping place, and the various groups of the basin are at such great distances from each other that we did not have time to devote to this geyser to the exclusion of the other springs. Dana and Grinnell saw this geyser in action twice in 1875. They say:

> The discharge took place in the evening, and was repeated again in the morning, lasting each time about 45 minutes. There was no single stream thrown to a great height, but a continued, confused mass of jets was thrown in all directions, with occasional spurts to a height of 30 or 40 feet. From its very irregularity it seemed to us one of the most attractive of the small geysers.*

We saw one eruption in 1871 estimated to be about 100 feet in height.

No. 4.—This is an irregular-bordered spring, 18 feet in length and 8

* Ludlow's Report.

feet in width at the widest part. In the bottom are two basins or orifices, one of which is yellow and the other black. The latter is the bubbling center of the spring, and is the point at which the temperature of 197° F. was noted. Below the spring are oozing spots and cavities in the deposit.

No. 5.—This is a spouting spring, with a basin 10 feet by 12 feet, surrounded by a bright-yellow rim. In the center of the basin are two irregular fissure-like orifices. There are two outlets or water-ways to this spring, one of which carries the water to the north and the other to the south.

No. 6. *Terrace Spring.*—This spring is easily recognized by its high mound, which is south of the Great Fountain. On the summit of the terrace-like mound is the spring, an oval basin measuring 8 feet by 12 feet. It is very deep, and the water has a dark, inky-green tint, almost black in places, The rim around the spring is raised from 3 to 5 inches, and formed of pointed masses of geyserite, which are yellow inside and grayish-white outside. At one end of the basin the water is in ebullition, and has a temperature of 201° F.

Beauty Spring.—This spring, which is one of the handsomest basins in the Lower Geyser Basin, was described as follows by Mr. Holmes in my report for 1872:

> It is isolated from the neighboring springs and nestled in against an abrupt bank, so obscured by tall pines that the visitor is liable to pass it by unnoticed. In approaching from the creek I passed up a gradually ascending slope down which the water flows, covering in its meanderings more than an acre of ground, and leaving, wherever it touches, brilliant streams of color. About a hundred yards (?) from the creek I came upon the spring, the waters of which stand nearly on a level with the surrounding surface. Approaching the border, I looked down into the blue, mysterious depth and watched the large bubbles of steam slowly rising to the surface and passing off into the air. The larger of these bubbles would lift up a considerable quantity of water, sometimes to the height of 3 or 4 feet, producing a kind of spasmodic boiling, and dashing a succession of waves against the rim. The spring is surrounded by an irregular rim, which stands a few inches above the general level of the water. The basin is 20 feet long and 10 feet wide, one end being narrower and partially separated from the main basin by an irregular row of beaded islands and projections.
>
> Although the spring and basin are very chaste and delicate in form as well as color, there are other springs more beautiful in those respects. But when I ascended the bank and looked down upon the spring and its surroundings, I concluded, without the least hesitation, that I had never seen anything so uniquely beautiful. On the upper side of the spring, next to the bank, the water in overflowing ran into large shallow pools, painting whatever it touched with the colors of the rainbow. Beds of rich, creamy white and rich yellows were interlaid with patches of siennas and purples, and divided up and surrounded by the most fantastic patterns of delicate grays and rich browns. On the side next the creek the running water has made a network of streams. In those where the water is still hot the colors are bright, varying from a creamy white to the brightest yellows, but as the water becomes cooler, farther down, the colors grow darker and richer, the siennas greatly predominating, while the basins of the larger pools are stained with still darker colors, frequently of a purple tint, and reflecting the picturesque groups of pines on their dark surfaces. Scattered irregularly over the whole surface are numberless little areas of dry deposit, from which the brighter tints have faded, but which still retain such a great variety of purple and blue grays that the harmony of the whole field of color is complete.

This spring, so well described by Mr. Holmes, is on the west side of the creek, and has periodical bulgings at intervals of a few minutes. The steam escapes with a throbbing pulsation. The temperature, 194° F., was taken on the edge.

White Spot Spring.—This is a small, unimportant spring on the side of the hill west of the Beauty Spring. Its temperature was not taken, and it is therefore not included in the table.

CRATER OF GREAT FOUNTAIN GEYSER LOWER FIRE HOLE BASIN

NEAR VIEW OF GREAT FOUNTAIN LOWER FIRE HOLE BASIN

No. 7 marks the location of a cluster of springs and steam vents near the creek on the north side, not far below No. 5. No. 8 is at the upper end of the cluster, in which there is a violent bulger (8 *e*), which has a triangular opening in laminated deposit. Its temperature is 199° F. On the opposite side of the creek (opposite Nos. 7 and 8) there are several springs not included in the table.

Springs Nos. 9–18 form a cluster, all but one of which is on the same side of the creek as No. 8, but farther south. They are principally located on a mound of deposit.

No. 9. This is a diamond-shaped pool 18 feet long and 8 feet wide, in which the water has a green tint, which contrasts well with the white basin in which it is contained. It is near the base of the mound, rather close to the creek, and has a temperature of 178° F.

No. 10 is on the summit of the mound, and is a very handsome cavern-like spring, with a white yellow-lined border surrounding greenish-tinted water. It is irregular in shape, measuring 20 by 30 feet in its greatest dimensions. One end of the spring has a hammer-head shaped prolongation, in which there is a black center of ebullition, where the temperature is 199° F., while in the pool it is only 182° F. Back of this spring is a ravine from which there flows a stream of pure, cold, drinkable water, which is an interesting fact to the visitor of this group, as in most parts of the basin he is in much the condition of Coleridge's mariner, surrounded with water, but "not a drop to drink."

Crossing this cold stream or rivulet we find the remaining springs of the cluster.

No. 11 is a nearly circular (9 feet diameter) gray-lined spring, with a white edge, in which the water has a bluish tint. The outlet is yellow lined. The water has a temperature of 181° F.

No. 12 is a spring of low temperature (146° F.), and, as is usual in such springs, it is lined with a leathery-looking substance (probably a variety of viandite) of red and greenish-brown colors.

No. 13 is a yellow and white lined basin, with rounded triangular sides, measuring, respectively, 4 feet, 5 feet, and 6 feet.

Nos. 14–17 are sufficiently described in the table.

No. 18 is on the opposite side of the creek, on the edge, and opens directly into it.

The next cluster (19–23) is on the west or southwest side of the creek, farther up, and are raised but little above its level.

No. 19 is a beautiful greenish spring, 15 feet in diameter, with a white border and a temperature of 182° F. It is back from the creek, next the edge of the timber.

No. 20 is a bulging hole back of No. 21, with which it is connected. The water is thrown up in a splashing mass, and has a temperature of 199° F., whereas in No. 21 the temperature is only 163° F.

A short distance above this cluster, on the same side of the creek, is another (Nos. 24 to 29).

Nos. 25 and 26 are long and narrow, and appear to be openings into a subterranean outlet from No. 24. There are several holes in the cluster that are not included in the table.

Some distance above this cluster, on the opposite (east) side of the creek, at the upper end of a small meadow, are three small basins, the principal one of which (No. 30) is a bulger and has a temperature of 189° F.

Crossing the creek again, we find on the west side a cluster (Nos. 31, 32) almost opposite No. 30. The principal spring (No. 31) is a large

triangular pool, lined with a vivid green deposit. It is at the base of the hill, and down the latter the water trickles into the spring over a red and green surface, the green being due to moss. The outlet of the spring has a white border in the grass. The temperature is only 157° F.

No. 32 is a small gray-lined spring, without an outlet, and having a temperature of 176° F.

No. 33 (*Black Spring*) is still farther up the creek on the west side, and is a clear spring, gushing from the side of the hill, 30 feet above the creek level. It is surrounded by a bare spot, covered with a black deposit, which spreads out over a large area on the slope below. It has a temperature of 162° F.

No. 34 is a clear spring on the east bank of the creek, above the Black Spring, at the falls. It has a temperature of 184° F. There are some dead pools in the grass above it, and also on the hill opposite are several. A small cone is noticeable. This spring is the last one noted in the ravine, although there are others above that are small and unimportant.

No. 35 is a large round spring, hidden in the timber east of the White Dome. It is about 40 feet in diameter and lined with brown leathery substance. Its temperature is 153° at the edge of the pool.

I have tried to compare the temperatures of 1871 with those of this year, 1878, and the result is given in the table below, which, however, is far from being complete. No temperatures were taken here in 1872:

Comparison of temperatures taken in the White Dome Group in 1871 *and in* 1878.

Number and name.	1871.	1878.
	° F.	° F.
No. 1	162–193	128–199½
Great Fountain	197	199
Beauty Spring	190	194
Cluster 9–18	166–194	168–199
Cluster 19–23	184–187	163–199
No. 30	180	189
No. 34	180	184

About 42 temperatures were taken in 1871, but the above are all that I can positively identify as being the same springs.

SIXTH OR RIVER GROUP.

Although this group is perhaps the largest in the Lower Geyser Basin, it is the least important as far as geysers are concerned. It includes all the springs on both sides of the Fire Hole River from the mouth of Fairy Fall Creek to the mouth of Fountain Creek. The table contains 147 temperatures, and these are by no means all that could have been obtained had time permitted. They are scattered over an area of about 1,300 yards by 500 or 600. In all the springs there is not one known geyser of any power, although there are many spitting or spouting springs which project the water to the height of a few feet. There are a number of the springs with small cone-like craters, and many large, handsome pools, with transparent water of beautiful blue and green tints. The springs present an infinite variety in structure; some are periodically agitated, others are constant boilers, and still others quiet pools, with gelatinous and leathery deposits. The ornamentation of their rims is varied and in most cases extremely handsome, as will be

seen from the descriptions of the most prominent springs, given after the table:

Table of Sixth or River Group.

Number and name.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1	Small spring, spreading out into pools in the marsh.	180			Below No. 1 are several other springs not enumerated.
2	3 feet diameter	131			Quiet red spring.
3	2 feet diameter	105			Above No. 2.
4. Fortress or Conch	Cone 18 feet across, 2 to 4 feet high.	201			Spouts, and has considerable overflow.
5	8 feet diameter	163			White basin.
5 *a*	10 feet diameter	105			Red basin, close to 5, really connected at times.
6	4 feet diameter	120			Turbid.
7	3 by 4½ feet	160			Turbid.
8	2 feet diameter	182			
9	1 by 2 feet	196			Back of No. 5.
10		184			White basins, with clear water.
11		180			
12	3 feet diameter	198			Bulging spring in hard basin.
13		175			Like 10 and 11.
14		150			All in hard, white deposit.
15		190			
15 *a*	(One end of 15)	170			
16		165			
17		198			
18		186			
19		178			
20		192			
21		160			
23		160			
24		165			
25		180			
26		155			
27		150			
28		178			
29	2 feet diameter	185			
30	18 inches diameter	159			
31	10 feet diameter	117			
32	3 by 8 feet	163			White basin.
33	5 feet long	160			White basin.
34	2 feet diameter	115			Red hole.
35	8 feet diameter on outside; 4 feet inside.	165			Gray-white basin, with bluish edge and yellowish border.
36	Small holes	150			
37	Small holes	117			Red.
38		147			Gray basin, with bubbling fissure close to it.
39	4 feet diameter	125			Red spring.
40	4 feet diameter	119			Red leathery lining on mound.
41		186			Gray holes
42		161			Small holes on white deposit.
43		195			
43½		155			Small holes on white deposit, with No. 42 and No. 43.
44		148			
45		181			
46	2 feet diameter	165			Clear spring, with white border.
47		143			Red pools, with others in grass near.
48		141			
49		157			Gray pool, with two apertures; others near it.
50	Are all on the same mound.	175	10.15 a. m.	48	Small.
51		128			Small red spring.
52		132			Small red spring.
53		183			Small.
54		181			Small gray.
55	15 by 6 or 8 feet	178			Geyser-like hole in gray deposit, greenish-tinted water, and yellow water outlet.
56	Cone	184			On river bank.
56½		168			
56¾		188			
57		133			Receives overflow from No. 55.

Table of Sixth or River Group—Continued.

Number and name.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		°F.		°F.	
58	Pool	188			Large greenish hole.
58 *a*	Cone	164			Cone.
58 *b*		190			Spring back of cone.
59	8 feet diameter	125			Quiet spring.
60		160			Gray spring near No. 46.
61	2 feet diameter	146			Below Fortress.
62		150			Red spring.
63	6 inches diameter	160			Middle of three holes of about equal size.
64	Small	115			Red spring.
65		161			Black-lined and white-bordered spring.
66		110			Red hole on cone.
67	2 feet diameter	151			White-bordered spring, with hole back, and other springs near it.
68	2 feet by 8 and 10 inches	180			White bordered, and on same mound with 67.
69	3 feet long, 18 inches wide	144			Oval spring on white mound.
70 *a*		170			Two white-bordered springs on edge of river bank.
b		190			
71		131			Red-lined spring on white mound.
72	18 inches diameter	152			Small white spring.
73	From 1 foot to 2 feet diameter.	105	1.15 p. m.	53	
74		125			
75		95			
76		130			
77	1 foot outside, 4 inches inside.	156			Sulphur lined.
78	6 inches diameter	150			Small white hole.
79		100			Small red spring.
80	1 foot diameter	130			Between No. 69 and No. 79.
81		185			On river.
82		175			Near No. 81.
83. Horn Spring	4½ feet high, 6 inches diameter at top.	196			Horn-like cone, near the river's edge.
84		160			Below Horn Spring.
85. Cone Spring	Cone rising 10 feet above the edge of river, 4 feet diameter, with orifice 2 inches diameter.	172			
86	5 by 8 feet	186			White-lined cavern-like spring on a mound of deposit, overlooking the river.
87	15 by 22 feet	161			Large cavern-like spring, with milky, blue-tinted water, on same mound with No. 86, but further from the river.
88. Bath Spring	40 by 45 feet	200			This spring is at the river level, and has a hard rim, corrugated. There is a large outlet towards the river. The spring was named on map made in 1872.
89. Cavern Spring	30 feet long, 8 feet wide at one end, near river, and 20 feet wide at other end.	162	2.15 p. m.	58	Beautiful quiet blue spring on edge of river below No. 88. Fronting the river is a rim, and at other end there is an overhanging edge.
90	40 by 40 feet	163			Blue cavern-like pool in gray basin.
91	6 by 10 feet	100			Red cavern-like hole near No. 90.
92	3 feet diameter	125			Red spring on mound near No. 90.
93	3½ by 3½ feet	191			Clear spring in hard geyserite, near No. 90.
94		165			Gray fissure-like spring.
95	4 by 8 feet	172			Gray spring.
96	4 by 4 feet	182			Geyser-like, with yellow-beaded basin.
97	4 by 5 feet	153			Gray spring.
98	9 feet diameter	106			Red pool.

Table of Sixth or River Group—Continued.

Number and name.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		°F.		°F.	
99		121			Red pools.
99*a*		126			
100		145			Turbid pools.
100*a*		135			
101		160			Clear white springs.
101*a*		165			
101*b*		164			Turbid spring.
Grotto	6 feet diameter	180			Mud spring against side of hill at the bend of the river.
102		118			Quiet spring on mound near river.
103	10 feet long by 4 feet wide.	146			This is a white spring with two basins.
104	20 by 40 feet	113			Lake-like red pool.
105	15 feet diameter	88			Circular spring, with green-tinted water. This spring is back some distance from those just described.
106		180			
107	35 feet diameter	130			Red-lined pool on large mound.
Crown Spring	4 feet diameter	169			White crown-like basin, with rim 4 inches high.
107½	3 by 5 feet	120			This spring is just back of the Crown Spring, and between it and No. 107 are others not taken.
108	30 feet long by 5 to 10 feet wide.	180			Oblong cavern, with white overlapping edge and beautiful blue-tinted water.
109		199			Geyser-like spring, with yellow masses lining it.
Mound Geyser	25 by 10 feet	199			Lined with yellow globular masses. Water was 3 feet below top when examined.
110	Cones 18 inches diameter each.	192			Small double cones.
Mound Cone	5 by 2 feet	196			Cone on oblong mound; boiling spring, in the cone, with rim 6 inches high.
111	6 by 8 feet	151			Between No. 110 and Mound Cone; yellow and green-lined funnel, with white border; slopes inside to two orifices.
River Cone		192			Four feet above the river.
		a=181			Two holes back of the cone.
		b=197			
Twin Cones	Each 18 inches diameter.	*a*126			These cones have quiet red springs.
		*b*135			
Fissure Cone	3 feet long	170			On the river, near the falls; has gray basin of clear water.
112	6 feet diameter, with orifice 1 foot by 6 inches.	112	9.15 a. m.	51	Red spring.
113	2 feet diameter	105			Red spring.
114		160			White funnel-shaped basin.
115	18 inches by 2 feet	180			Water rises in pulsations.
116	4 feet diameter	195			Gray spring, with water 1 foot below the surface.
117	4 by 7 feet	176			Oblong spring, with small spouter back of it.
118	12 by 15 feet	142			Green pool, with red border.
119	5 by 8 feet	195			Oblong spring; boils and spouts 6 inches at times.
120	10 by 15 feet	197			Bubbler.
121	Fissure in hard deposit.	156			Basin white, with greenish-tinted water.
122	8 feet diameter	126			Circular pool.
123		180			Fissure.
124		120			Red pool.
125	10 by 15 feet	175			Gray pool, with fissure.
126	1 foot diameter	180			Hole in hard deposit.

DESCRIPTION.

Springs Nos. 1 to 61 form a subgroup on the east side of the river, extending north from the mouth of Fountain Creek. Nos. 5 to 35 and No. 59 are on the top of the bank, or mound, and are divided into three clusters. The remainder of the springs in the subgroup are on the slope of the mound nearer the river. There are only two springs here that merit description, and these are the Fortress and No. 58.

No. 4. *Fortress Geyser, or Conch Spring.* (Plate XII).—This is supposed to be a geyser, from the fact that it has built up a mound, or cone, although it has never been seen in action. It is near the river, at the lower end of the sloping bank, and is about 18 feet in diameter. It is 2 feet high at the back and four feet in front, on account of the slope in the bank. This crater is about a foot in thickness, and beautifully beaded with pink and gray geyserite. Its sides are broken with openings something like port-holes, whence the name. The water boils furiously, so that the mass is thrown up 4 to 5 feet above the crater. The overflow is carried off through a channel in a raised water-way, which is two feet in height. This channel is about 6 inches in width and a couple of inches in depth. The water has a temperature of 201° F. There are periods of activity which are followed by a cessation of the boiling, when the water falls in the crater and there is no overflow.

No. 58 is below the Fortress, and is a large basin in the laminated masses of deposits which extend in tables over a portion of the spring. It is filled with greenish-tinted water, in which the temperature is 188° F. Back of it is a small bowl, or cone, 2 feet in height, with a flat top, in which the temperature is 164° F., and back of this is another part of the spring (*b*), in which the temperature is 190° F.

Springs Nos. 62–65 form a sort of cluster on the line of the drainage from cluster 31–35, but nearer the river the area in which they are situated is marshy, and beyond them we have a large cluster of springs at the foot of the low bluff. Here only a few temperatures were taken (Nos. 66–85) compared to the number of the springs. I shall mention only two of the group, as they are mainly small and unimportant.

No. 83. *Horn Spring.*—This is one of several cones near the river. It is 4½ feet high and 6 inches in diameter at the top, with a much broader base. The temperature was 196° F. The water is in constant ebullition.

No. 85. *Cone Spring.*—This is a large cone rising about 10 feet from the edge of the river. It is 4 feet in diameter on top, with an orifice only 2 inches in diameter. The temperature was 172° F. There is besides this a horn-shaped mass of deposit on the edge of the river.

Following down the river from the cones we find several springs on a high mound.

No. 86 is near the edge of the mound and is a white, cavern-like spring, with a temperature of 186° F.

No. 87 is the main spring on the summit of the mound, and is a cavern-like basin 22 feet long and 15 feet wide, with milky, blue-tinted water, with a temperature of 161° F. The mound breaks off abruptly beyond these springs; and just across a ravine filled with muddy pools and steam vents we find the next spring, which is—

No. 88. *Bath Spring.*—This handsome boiling spring is at the level of the river, from which it is separated only by a narrow run of hard, corrugated geyserite. It has a rather square-shaped basin about 40 feet across. It was named Bath Spring in 1871, although the water is not

FORTRESS GEYSER LOWER FIRE HOLE BASIN

at all suitable for bathing, having a temperature of 200° F. A short distance below this is another handsome spring—

No. 89. *Cavern Spring.*—This also was named in 1871, and is a beautiful, quiet, blue spring, with extremely transparent water. It is on the edge of the river, from which it is separated by a narrow rim. This part is the narrowest portion of the basin, being only 8 feet wide, and from this edge the bottom of the basin slopes away from the river into a deeper pool, 20 feet in width, at the back of which is an overhanging edge. The temperature of the water is 162°, which is only 1° more than that observed in 1871, showing that the spring has not changed since then Back of Nos. 88 and 89 is a large cluster of springs (Nos. 90, 91) which are comparatively unimportant and extend some distance north at a little distance from the river.

The next cluster is somewhat isolated from those already described, and is located opposite the island at the bend of the river.

The *Grotto* is a mud spring 6 feet in diameter, at the base of the hill, with a temperature of 180° F. There is also a white mud pot near these springs (102–104), which are mainly quiet springs, with a considerable deposit of iron. There are a number of springs and pools in the grass that were not given in the table.

No. 105 is east of the cluster just referred to, and is an isolated circular spring 15 feet in diameter, with greenish water.

All the springs hitherto described in this group are on the east side of the Fire Hole. Those remaining are on the opposite side, and beginning at the north we have first the Crown Spring, which is a circular, white basin 4 feet in diameter, with a rim 4 inches high. It is somewhat crown-shaped, on a mound, and has a temperature of 169° F.

Nos. 107 and 108 are two springs south of the Crown Spring, and are surrounded by other springs and vents. Near them, also, are several lake-like ponds.

Proceeding southward we soon reached the mound opposite the falls, or rapids, of the river.

No. 109 is a geyser-like spring, with globular, yellow masses lining it. The water outlets are also yellow lined, and there are many fissures in the mound around it. The temperature is 199° F. This is probably a geyser.

Mound Geyser.—Although never seen in action, this is probably a geyser. It has a basin 25 feet long and 10 feet wide, in which at the time of our examination the water was 3 feet below the top. It is lined with handsomely-ornamented yellow globular masses of geyserite. It was seen bulging several times, but no active spouting was observed. The temperature of the water was 199° F. This is the same as in No. 109, and the ornamentation of the basin is also similar. South of these, which are the two important springs of this cluster, are a number of cones similar to those on the opposite side of the river. They are sufficiently described in the table. On an island opposite them, near the eastern bank, are the Island Cones, which were not closely examined. South of the cones are a number of springs not examined. The next cluster (113–118) is on a flat opposite the Fortress. There ar no important springs here. Still farther south is a cluster (119–123), most of which are in hard deposit. Crossing the river, now we find the last cluster above (south of) Fountain Creek, at the foot of a marshy area near the river. They are 124–126, and are, with the exception of No. 125, small, rather obscure holes.

In 1871 only 95 temperatures were taken in this group, the highest

being 196°F. The springs were not mapped with sufficient accuracy to identify them all, but the following gives the comparison of the temperature of those that are undoubtedly the same springs:

Spring.	1871.		1878.	
	Temperature of spring.	Temperature of air.	Temperature of spring.	Temperature of air.
	°F.	°F.	°F.	°F.
No. 4, Fortress	196	70	201	48
No. 86	191	70	186	53
No. 87	166	70	161	53
No. 88	183	70	200	58
No. 89	161	70	162	58
Mound Geyser	196	70	199	51

On the accompanying map of the Lower Geyser Basin, only the numbers of the most important springs are given, especially on the east side of the river.

GOOSE LAKE MUD SPRINGS.

These mud springs are situated near a small lake or pond (named Goose Lake in 1872) a small distance east of the active boiling springs of the River Group. There are from 30 to 50 springs in the group, which are of all sizes from a few inches to 20 or 30 feet in diameter. They are boiling, sputtering, and spouting springs, in which the mud is of all consistencies, from that of a simply turbid or muddy water to that of stiff mortar. The colors are white, brown, and lead-colored blue. Some of them are deep pits 15 to 20 feet in depth, at the bottom of which the mud sputters and spurts at times above the rims of the craters. One of these, near the lake, is nearly forty feet in diameter and is in constant action. Surrounding it are a number of small mud cones, 4 inches to a foot in height, which keep up a simmering noise. They are steam vents, and on breaking them open they are seen to be streaked with sulphur and iron stains. Some of them are lined with crystals of sulphur. Sulphur is found at one other locality in the Basin, but is more prominent here, although not nearly so abundant as at many of the localities on the Yellowstone.

SEVENTH GROUP OR FAIRY FALL SPRINGS.

Under this head I include all the springs found along the course of Fairy Fall Creek, although they are readily divisible into two groups. The creek is named from the fall at the head of the valley called Fairy Fall by its discoverer, Colonel Barlow, who determined its height to be 250 feet. The creek rises in the plateau south of Twin Buttes and turns around them, flowing a little east of north for about 4 miles to the Fire Hole, which it joins a short distance above the mouth of Sentinel Creek.

On the south side of the buttes there are some springs in the timber, their presence being revealed by the columns of steam. They were not visited, and I cannot, therefore, present any description of them.

The principal springs are out in the open valley. The upper subgroup comprises the springs included under Nos. 1 to 15, most of them

being on the west side of the creek below a marsh east of the North Butte. The remainder of the springs form a well-defined subgroup farther down stream, just above a marshy area. As usual, I present a table of the group.

Table of Fairy Falls Group.

Number.	Size of spring.	Surface temperture.	Time of observation.	Temperature of air.	Remarks.
		° *F.*		° *F.*	
1	Basin 15 by 20 feet, orfice 3 by 4 feet.	150	.....	.....	Large flat basin.
2	.....	171	.....	.....	Spring on a small mound.
3	Hole in ground.....	200	.....	.....	Water bulges out from under a rock. It receives water from No. 4.
4	3 by 4 feet	195	.....	.....	White basin on a hard mound.
5	4 by 4 feet	200	.....	.....	Strong escape of water.
6	Black fissure	197	.....	.....	A bulging spring.
7	2 feet diameter.....	199	.....	.....	Black, bulging spring in hard deposit above No. 6.
8	Fissures	186	.....	.....	Black deposit.
9	15 feet diameter.....	181	.....	.....	Black-lined, cavern-like spring.
10	25 feet diameter.....	186	1.30 p. m ..	48	Basin and fissure.
11	5 by 7 feet	197	.....	.....	Inky-black pool.
12	3 by 4 feet	157	.....	.....	Green and red lined spring with sandy center; bubbles occasionally.
13	45 feet diameter.....	123	3.20 p. m ..	55	Leathery-lined, flat spring, with terrace.
14	7 feet diameter.....	194	.....	.....	Bulging spring.
15	5 by 6 feet	120	.....	.....	Red, quiet spring, with tufted lining.
16	5 feet diameter.....	161	.....	.....	Black sand basin, no rim. 20*a*.
17	6 by 10 feet	131	.....	.....	White and yellow gray basin.
18	.....	198	4 p. m.	50	Gray-edged border.
19	10 feet diameter.....	85	.....	.....	Red spring.
20	5 by 10 feet	130	.....	.....	Green lined.
20*a*	3 feet diameter.....	140	.....	.....	
21	10 by 15 feet	80	.....	.....	Pinkish-red spring, clam shaped.
22	20 feet long	105	.....	.....	Pear-shaped.
23	3 feet diameter.....	182	.....	.....	Broken hole.
24	8 feet long	130	.....	.....	Oval, red and green lined.
25	4 by 5 feet	155	.....	.....	Yellow-lined.
26	8 feet long	140	.....	.....	Pear shape, red lined, with white border.
27	18 feet diameter.....	157	.....	.....	Glass-green, cavern-like hole, with white basin; fissuer-like on edges.
28	40 feet diameter.....	135	.....	.....	Greenish pool in a basin; the run of the pool is 2 to 4 feet from the edge.
29	.....	195	.....	.....	Clear white-rimmed spring, with scalloped edge.
30	5 feet diameter.....	125	.....	.....	Reddish basin.
31	6 inches by 1 foot	197	.....	.....	Two bubblers in beaded cones.
32	2 feet diameter.....	190	.....	.....	
33	6 inches diameter	196	.....	.....	Bubbler.
34	2 feet diameter.....	175	.....	.....	Flat white springs, with small openings 4 inches in diameter.
35	5 feet diameter.....	172	.....	.....	Old geyser tube in basin of hard geyserite.
36	.....	.....	.....	.....	Red spring between 34 and 35. There are a number of holes in the grass.
37	.....	162 180 190	.....	.....	Several holes on a mound.
38	4 by 10 feet	105	.....	.....	Pink-lined.
39	4 by 8 feet	170	.....	.....	Deep hole, with hard geyserite rim..
40	Pool 20 feet long	*150 †190	.....	.....	White pool, with a spring back of it.
41	30 feet long	120	.....	.....	Reddish, leathery-lined, heart-shaped basin.
42	10 by 12 feet	140	.....	.....	Rather deep, green-lined basin.
43	5 by 8 feet	110	.....	.....	Greenish and red basin.
44	20 by 25 feet	162	.....	.....	Deep, gray-lined cavern, square opening, with blue-tinted water.
45	.....	196	.....	.....	Yellow spouter.
46	.....	.....	.....	.....	Pool, with water 3 feet below surface.
47	10 feet diameter.....	175	.....	.....	White spring.
48	15 by 25 feet	174	5 p. m.....	48	Turbid, blue spring, with white edge.
49	20 by 30 feet	145	.....	.....	Boat-shaped, with green-tinted water.
50	.....	165	.....	.....	Handsome blue cavern.
51	3 by 4½ feet	177	.....	.....	Oval basin.
52	15 feet diameter.....	142	.....	.....	Yellowish basin.

* Pool. † Spring.

DESCRIPTION.

Nos. 1, 2, 3, and 4 do not deserve special mention.

No. 5, *Locomotive Spring*, is probably the most important spring in the group. It has a black basin, 4 by 4 feet, of boiling water, from which there is a strong overflow through a black-lined water-way. The temperature in the basin is 200° F.

Alongside the spring is a steam vent, evidently connected with the spring, from which the steam escapes with a sound that at a little distance exactly resembles the escape from the waste-pipe of a locomotive.

The next spring I will mention is—

No. 10, which has a basin 25 feet in diameter, in which there is a fissure from which the water boils. The deposit about this spring is black and white. Back of it is a red spring.

No. 11 is a rectangular pool measuring 5 by 7 feet, in which the water has a black, inky tint, with a temperature of 197° F. The border is of hard, white, scalloped geyserite, with a black edge. Arm-like processes extend out into the spring.

Below Nos. 10 and 11 are two lake-like ponds. As shown on the map, there are other springs in the vicinity that were not examined. Those to be described next are across the creek, *i. e.*, on the east side.

No. 13. This is a large, flat spring, about 45 feet in diameter, with terraces outside. It is lined with a leathery-like substance (viandite ?), and in the center is a basin or bowl about 3 feet in diameter. The temperature is only 123° F.

No. 14 is a white and gray pebbled basin, 7 feet in diameter, flat, with a central orifice which measures about 2 feet across, and from which the water rises in pulsations or bulges, which sends waves to the sides of the basin. Nos. 15, 16, and 17, described in the table, complete the subgroup.

I have tried to compare the temperatures I obtained with those obtained in 1871, and indicated on the map then prepared, but find it impossible to identify the springs on the latter. The highest temperature given there is 196° and the lowest 142°.

Of the subgroup next to be described, Nos. 18 to 26, inclusive, are on the east side of the creek, partially concealed by timber. They nearly all have broad, circular mounds a foot or two in height. The springs are handsome, but it was late in the evening when we plotted the springs, and little time was allotted to their detailed examination.

No. 22 is a pear-shaped, greenish-brown basin 20, feet in length and 10 feet wide at the widest part. On the north side the rim was a foot high. The temperature was 105° F., one of the lowest recorded in the group.

No. 26 is of similar shape but with a white border. No. 18 had the highest temperature (198° F.), being a boiling spring.

These springs are surrounded by an area of white siliceous deposits and are back from the creek some little distance, and Nos. 24, 25, and 26 are separated from the others by timber. There is no appreciable drainage from any of the springs.

Crossing the stream, now, we find a large number of springs (Nos. 27 to 52), many of which are very interesting. We were obliged to work rapidly in examining this subgroup and the table therefore contains most of the information obtained. Besides the springs there enumerated there are many minor ones besides mere vents that are not included in the table, as it was impossible in the limited time to map any but the main springs.

No. 49 is a peculiar-shaped basin 20 by 30 feet. It is somewhat like a boot in shape, and has a white basin with a white rim, in which the water has a green tint. At one end is a deeper pool which is yellow in color. The temperature was 145° F.

No. 50 is a blue, cavern-like spring, with an overhanging white edge, which reaches several feet over the spring. The water is of a handsome bluish-green tint and has a temperature of 165° F.

As the table shows, only a few of the springs have high temperatures, 196° F. (in No. 45) being the highest. The highest temperatures are in the bubbling and spurting springs. In 1871 a temperature of 198° F. recorded in was one of the springs of the group. At the lower end of the marsh, situated at the base of a low hill, is a constantly-boiling spring, which has a peculiar toadstool-like rim and sends forth vast columns of steam. In 1871 it had a temperature of 196° F.

EIGHTH OR SENTINEL GROUP.

This group of springs was discovered in 1872, and is indicated on the map made in that year as the Eighth Group. Professor Bradley thus describes the discovery:

> From our camp on the east side of the Lower Basin we saw on several occasions tall columns of steam rising from near the foot of the ridge on the extreme western side of the basin, but at first referred them to the cluster among which we had camped on the evening of our arrival. But upon examination we found a considerable stream coming from west of the Twin Buttes, which had not been seen by previous explorers, and whose valley included a cluster of large geyser mounds, from which these columns of steam must have escaped. Though this group was visited on three different occasions, none of us were so fortunate as to witness any eruption from these vents. On entering the valley from below we see before us a range of four large mounds running diagonally across it. The two central ones are the highest, and appear so much as if they were guarding the Upper Valley that this was called Sentinel Branch.*

Sentinel Creek, as laid down on the map of 1872, is not exactly right, as a comparison with the map accompanying this report will show. We followed it from its mouth and carried a meander line from the Fire Hole to a point above the springs. Just below the springs the valley begins to widen, and is to a great extent a marsh, in which there were probably once numerous springs. The creek flows through it in a deep channel, with muddy banks, which make the crossing difficult, as we found on several occasions. The active period of this basin has probably been long passed, and in the isolated mounds we see only the monuments of what were once powerful geysers.†

It is probable that the only geyser now active in this basin is the one to which I have given the name Rosette. I judge from Professor Bradley's description that this geyser was not seen by him in 1872. I shall now give the springs of the group in tabular form and then describe specially those that appear to me to be of sufficient importance to deserve it.

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*Report U. S. Geol. Surv. for 1872, 1873, p. 237.

†Mr. Norris calls this Basin Geyser Meadows. See his Report for 1881.

Table of Eighth or Sentinel Group.

Number.	Name.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
			°F.		° F.	
1	Flat Cone	9 feet diameter	200			This spring is on a high mound. Water rises and falls; boiling, periodical.
1*a*	Small Cone	10 inches diameter	165			
2	Rosette Geyser	Basin 20 feet diameter, geyser 1 by 2½ feet.	196*			Has a basin filled with rosette-like pebbles; spouts 10 to 30 feet.
3		Two openings, each about a foot diameter.	198			Yellow-lined. oblong, flat mound.
4		2 by 3 inches	190			1 foot diameter outside.
5			195†			Beaded mound, 6 inches high.
6			199			Irregular, yellow-lined hole; mound 1 foot high.
7	Steep Cone	8 feet diameter	199	9.45 a m.	45	This spring is on a high mound like No. 1. It boils vigorously, and sometimes bulges a foot or more.
8	Mound Spring	12 by 15 feet	201 *a*194 *b*195			Boiling spring like 187; mound is flatter; *a* and *b* are vents alongside.
9	Red Terrace	60 by 20 by 25 feet	190			Lake-like spring, bulging at one end.
10		40 by 25 by 18 feet, double spring.	*a*132 *b*140			Green-lined pool, circular at each end. It is in timber.
11		Basin is 6 feet diameter, 18 inches deep; fissure in center 2 feet by 6 inches.	175	10.45 a. m.	49	White basin lined with yellow globular masses.
12		2 by 3 feet	193			Sloping, beaded edge; bubbles.
13	Bulgers		*a*190 199		49	Yellow-beaded silica separates the two openings, and a yellow and red water-way carries off the overflow.
14			198			Small fissure-like hole.
15		3 by 5 feet	135			Clear spring, with mud-holes beyond it.
16		2 feet diameter	197			There are other small holes near by.

* At low water.

† With water down.

DESCRIPTION.

No. 1. *Flat Cone.*—This is the first spring met with on the north side of the valley. It is on the top of a mound of gray geyserite that rises between 15 and 20 feet above the surrounding level, and has a diameter of about 55 feet on the summit. It is of course much larger at the base. It was named Flat Cone Geyser in 1872, although mound would be a better designation than cone. I do not think it is a geyser, as the spring on the summit is regularly agitated, and the surface of the mound shows no evidence of any spouting. The spring basin on the summit of the mound has a diameter of about 9 feet, and has a dark brown rim which is raised 6 to 8 inches. The water rises and falls, and has periods of very active ebullition. The temperature of the water was 200° F. The temperature obtained by Professor Bradley in 1872 was 197° F. Just outside of the spring is a small cone 10 inches in diameter and a foot in height, in which the water has a temperature of 165° F. The spring is not in the center of the mound, but near one side, and outside the mound has considerable standing water.

Nos. 2–6 form a cluster a little west and north of the Flat Cone. They re on a platform of deposit which is only slightly raised above the gen- ral level. When the water is low in No. 2 all the others appear to ave low water, so that there is evidently some connection between hem. Only one was seen to spout, although the character of the de- osit about all of them indicates that they have periods of eruption. his is the cluster mentioned by Professor Bradley, as follows:

> Still going westward we find in the extreme edge of the valley, on the top of a low mound, a cluster of four vents (there are really five, although one is very small), from 1 to 2½ feet across, quite irregular in shape, and all boiling too violently to allow one to take the temperatures. All were surrounded by bead-like incrustations. I judge that they all spout moderately.*

No. 2. *Rosette Geyser.*—I have given this name to the only known geyser in the group from the occurrence in its outer basin of beautiful rosette-covered pebbles. Some of these are white on a black ground, others are pink or slightly yellow, and others are pearly. The basin of the geyser is about 20 feet in diameter in its outer dimensions, in which the central orifice or bowl is about a foot in diameter. Surrounding this orifice the inner basin is 2½ feet diameter, lined with beautiful yel- lowish-tinted beaded silica. Only one eruption was noted, and this attained a height of about 30 feet as estimated from a distance. The temperature of the water taken some time after, when it was some dis- tance below the surface, was 196° F.

No. 3. The mound of this spring or geyser is oblong and raised 6 or 8 inches, beaded on the outside, and is rather flat on top. Each of the two openings is from a foot to a foot and a half in diameter, and the tem- perature was 198° F.

No. 4 is a small hole close to No. 3.

Nos. 5 and 6 are much like No. 3 in the character of the deposits. The temperatures (195° and 199°) were taken when the water was some dis- tance below the surface. These springs, although few in number, and small, are about the most active in the group, and are, I think, the source of most of the steam that is noticed rising from this locality when one is a distance from them, although the mound springs may have periods of violence when they give off large volumes of steam.

No. 7. *Steep Cone.*—This cone or mound is 20 or 25 feet high, of about same dimensions as No. 1, and is on the right bank of the creek, in bend which it has probably caused. The stream has cut into its western side and may ultimately be the cause of its destruction. The spring on summit is nearly circular, about 8 feet in diameter, and like the spring the Flat Cone. It has a dark yellow-brown rim raised about 6 inches and handsomely frilled. The deposit on the outside is white stained with yellow. There are four small channels which carry off the overflow over two sides of the mound. The water in the spring has an inky tint and boils vigorously and has a temperature of 199° F., which is 1° more than that observed by Professor Bradley in 1872. In all respects this spring is similar to the one on the Flat Cone.

No. 8. *Mound Spring.*—This is indicated on the map of 1872 as Cone Spring, but the latter name is so inappropriate that I have changed it to Mound Spring. The mound is very flat, low compared with the two principal ones (Nos. 1 and 7). It soon fades out into the general level and has on its summit a handsome oval spring and two small vents (*a* and *b*). The former has a white basin 16 by 12 feet, in which the water is of a green tint. The rim, which is beautifully scalloped, is raised only 3 or 4 inches, and is flat on top. White cake-like pieces of deposit extend

* Report U. S. Geol. Survey of the Terr. for 1872, 1873, p. 238.

into the water, which has a temperature of 201° F. This temperature i 3° more than that obtained by Professor Bradley in 1872, due, perhaps, t an increased activity in the spring at the time of my observation. Th water flows from the spring through a beautiful white-lined channel The two vents have temperatures of 194° F. and 195° F.

No. 9. *Red Terrace Spring.*—This is a lake-like pool 60 feet long by 2 to 25 feet wide. It is on the south side of the valley, back from th creek, and is conspicuous on account of the brilliant color displayed o its terraces. These terraces are like those of Gardiner's River on very small scale, and are at the north end, where the pool is very shallow The water from the pool spreads out over them and deposits ferric oxid on cooling. The active part of the spring is at the south end, where th water is of a handsome blue tint and is bordered with a gray and yel low rim of coral and mushroom-like forms of geyserite. Dense cloud of steam are given off from this part of the spring, and the water bulge constantly during the time our observations were made. The temper ature was 190° F. Professor Bradley, in 1872, recorded 187° for th pool. About 2 feet from the south end of the pool is a small geys like cone 6 inches high.

No. 10 is a green-lined pool with two basins separated by a const tion. The total length is about 40 feet and the diameters respecti of the two basins, 18 feet and 25 feet. The temperature in the sma *b*, is 140°, and in the larger, *a*, 132°. There is a slight bubblin the surface, and the outlet is by No. 8. This pool is in the timber, there are others in the vicinity that were not noted.

Iron Pot.—This is a deep, crater-like hole, with smooth, dark sides is about 6 feet in diameter, and was named by Professor Bradley. water is 6 feet below the surface, although seen to fill the basi Professor Bradley on one occasion in 1872. The deposit is red brown in color and mainly siliceous, the color being due to the contained in it. This spring is near the foot of the spur south of Sheep Cone.

Nos. 11 to 16 form a small group or cluster on a flat mound sout the Sheep Cone, between it and the Iron Pot.

No. 13, which is really two springs in one basin, being separated by a band of beaded silica, and is the principal spring in the clu having the highest temperature, and being in active ebullition stantly. The deposits about the spring are very handsome bea pearly masses.

No. 11 is the largest spring and No. 14 the smallest, being merel fissure-like hole. The temperatures obtained in this group in 1872 w from 191° F. to 193° F.

The mounds which are so conspicuous in the valley of Senti Creek are, I think, the craters of old geysers which have become tinct as geysers by the closing up of the orifice, so that now we ha only the small springs on the summit, which are secondary in th formation. I do not believe that at the present time any of them a veritable geysers.

HALF-WAY GROUP OR EGERIA SPRINGS.

This group of springs was designated the Half-way Group in 187 because it was some distance up the river (about two miles above t open portion of the valley). It is, however, within the limits of t Lower Basin, the cañon which separates the latter from the Upper Basi beginning just above the Egeria Springs. Since 1871, also, the extent

MAP
OF THE
LOWER GEYSER BASIN
YELLOWSTONE NATIONAL PARK

PLOTTED BY HENRY GANNETT M.E.

AUGUST AND SEPTEMBER

U.S. GEOLOGICAL SURVEY

1878

he basin is better known, and if we include the Fairy Falls Group and he Sentinal Creek Springs, we must include the Egeria Springs. The osition of the springs is not indicated on the map of the Lower Basin, ut the detailed map gives a good idea of this exceedingly interesting nd important group of springs. They are principally on the left bank f the river, although the only *known* geyser at the time of our visit in he group is on the right bank, close to the trail. The springs occupy n area extending along the river about a mile in length and a quarter f a mile in width. The river, as it comes from the cañon valley above, makes a sharp turn or bend about opposite the center of the group. The main springs are at the lower or north end, on a mound which is about 50 feet above the river level. The following table catalogues the springs:

Table of Half-way Group or Egeria Spvings.

Name or number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.			
1. Grand Prismatic Spring.	250 by 350 feet	*146			This is probably the largest spring in the Fire Hole Region.
2. Turquoise Spring.	100 by 100 feet	171			Square lake-like blue-tinted spring. Receives some of the overflow from No. 1.
3. Cliff Caldron or Excelsior Geyser.	200 by 330 feet	175			A great boiling caldron. It was impossible to take the temperature anywhere except near the outlet.
4	80 by 150 feet	Cold	12.10 p. m.	57	Turbid blue pool with gray basin. Receives water from No. 1.
5	20 feet diameter	135			Light-blue spring with white basin. Receives some of the overflow from No. 1.
6. Indigo Spring	20 by 25 feet	196			Dark blue boiling spring, triangular in shape.
7	*a* 5 by 8 feet	169			These springs bubble gently.
	b small oblong pool	125			
	c 3½ foot diameter	151			
8	9 by 12 feet	173			White basin, bubbling rapidly.
9	2 feet diameter	190			Clear bubbler with two openings. There are others close by it.
10	*a* 6 inches diameter	194			Two small holes.
	b 6 inches diameter	195			
11	22 feet diameter	174			Cavern in center about 9 feet in diameter, in which the water is of a bluish-green tint; boils gently.
12	2 by 4 feet	190			White-lined basin which boils gently.
13	2 by 3 feet	197			Spouting hole with a fissure at the bottom 2 to 3 inches wide.
14	10 by 15 feet	105			Greenish hole at the end of a red shallow pool.
15	10 by 20 feet	150			Basin red at one end and white at the other.
16	10 by 15 feet	65	1 p. m.	57	Red hole. Receives water from No. 14.
17	25 by 30 feet	172			Gray basin with cavern-like hole 15 by 20 feet.
18		117			Greenish pool with a red basin.
19	20 feet long, 8 to 10 feet.	170			Gray spring with black center.
20	15 by 18 feet	130			Oval red pool with gelatinous border.
21	10 by 20 feet	182			Cave-like spring in conglomerate sandstone and geyserite.

*On north edge.

Table of Half-way Group or Egeria Springs—Continued.

Name or number.	Size of spring.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.			
22	2 holes, each 1 foot diameter.	160 160			
23	6 inches by 1 foot	186	2 p. m.	59	Small white hole with white scalloped border.
24	3 by 8 feet	190			Clear spring with black and gray basin; spouts at one end, splashing against the other.
25	2 by 5 feet	184			Gray and white spring with two white funnel holes.
26	20 by 25 feet	150			Deep white fluted basin with triangular funnel and green water.
27	3 feet diameter	180			Chimney-like hole in hard deposit.
28	25 feet diameter	183			Large blue cavern.
	a 5 feet diameter	197			Boiling spring.
29	25 by 28 feet	195			Gray basin with white edge. There is a deep blue cavern at one end.
30	40 by 50 feet	179			Green cavern-like spring 15 to 20 feet below the surface.
31. Pebble Spring	Flat basin 6 feet diameter.	191			Bubbler in which the water spouts 6 inches or a foot from a hole 3 inches in diameter.
32. Catfish Geyser of 1871.	Cone 5 feet high	194			Horn-like fissure. Spouts 6 inches to a foot.
33	Basin 8 feet diameter	197 *a* 196 *b* 185			Bubbler like No. 31. Orifice is about a foot in diameter.
34	1	171			White-lined holes.
35		195	3.30 p. m.	56	Bulging spring at the foot of the bluff. Steam comes out in large bubbles.
36	15 feet diameter	156			Yellowish-green spring.
37	5 feet diameter	163			Gray spring on edge of river.
38	Geyser				
39	Pool				

DESCRIPTION.

No. 1. *Grand Prismatic Spring.*—This is perhaps the handsomest spring in the whole Park, and it is certainly one of the largest, if not *the* largest. It measures 250 by 350 feet. I have named it Prismatic on account of the brilliant coloring displayed in it. The steam generally obscures the view, but the best point to see it is from the point on the bluff on the opposite side of the river. Over the central pit or bowl which is constantly boiling and sending up vast columns of steam, the color is a deep blue, which fades into green towards the edge. The surrounding shallower basin has a yellow tint, fading into orange, and outside the rim is a brilliant red deposit. This fades into purples, browns and grays, the whole being on the gray-white ground of the deposit forming the mound on which the spring is situated. These colors are vivid and perfectly distinct. No imagination is needed to distinguish them, but they stand out in well-marked bands.

When we visited these springs in 1871, Mr. Thomas Moran, the artist accompanied us, and made water-color sketches of the springs, which show these vivid colors, as did also Mr. W. H. Holmes. As time elapsed after our return our recollection of the coloring naturally became less and less distinct, and we began to think perhaps the colors shown in the

GRAND BLUE SPRING, LOWER GEYSER BASIN.

sketches were a little too bright. The visit of 1878, however, proved to us again the truthfulness of the pictures. A view of the spring here described will convince any one, no matter how skeptical, that the colors cannot be exaggerated.

As I have already stated, the spring is on the summit of a mound, which, as shown in the walls of the next spring to be described, is built up of layers of the siliceous deposit. The water, which flows away from the spring in all directions, rises and falls in a series of wave-like pulsations, which has formed a succession of terraces, especially at the south end, where they have formed steps several inches in height. The small raised rim is a series of beautiful large scallops. The temperature of the water at the north end near the edge was 146° F.

Our observations do not show whether or not there is any periodicity in the activity of this spring, but the indications are that it is not a geyser, although closer observations are needed to prove the fact.

No. 2. Turquoise Spring.—This is a deep, blue tinted, square spring, measuring 100 by 100 feet, below No. 1 and to the left of No. 3. The color is intense in hue. Near the outlet is a white shelf projecting a short distance into the spring, and over it the water is shallow. The temperature of the water at the south edge is 171° F. The comparatively low temperature is probably due to the fact that part of the water is derived from the overflow of No. 1. On the map of 1871 I find the temperature of 190° F. given for a spring which appears to occupy about the position of this one, but the map is not correct enough to identify it positively. The water outlet is like a trough, 6 or 8 inches in depth and 18 inches to 2 feet in width. It is of a brilliant white on the bottom, with white and yellow edges. As the river is approached the channel is yellow, with a salmon-color edge. It joins one of the outlets from No. 3, and through it there is a rapid and strong flow of water, a large part of which is actually from the spring, and not from the overflow of No. 1. The name has been given from the tint of the water, which is the blue of the turquoise.

No. 3. *Cliff Caldron* or *Excelsior Geyser* (Plate XIII).—Equally interesting with the Grand Prismatic Spring is the one to which I have given the name of Cliff Caldron. We called it the caldron in 1871, to which I have added the name given it by Professor Comstock in 1873. It is an immense pit, of rather irregular outline, 330 feet in length and 200 feet wide at the widest part. The water is of a deep-blue tint and is intensely agitated all the time, dense clouds of steam constantly ascending from it. It is only when the breeze wafts this aside that we can see the surface of the water, which is 15 or 20 feet below the level surrounding. The walls are perpendicular, cliff-like, and sometimes overhang, and are found on three sides, having been worn away at the outlet. The deposit in which this pit is cut is laminated old spring deposits, showing that this spring is secondary in its formation. It is probable that when the laminated deposit was laid down, the spring on the summit (No. 1) was the main spring and of vastly greater extent. It appears that this spring broke out near the river and has been working backward, the constant undermining of the deposits constantly enlarging the basin of the spring. Large masses have broken off the edge and have tumbled in. Towards the river the walls become less high, as the top has the slope of the mound which is in that direction. There is an immense column of water pouring from the spring, which soon spreads out on terraces and finally pours over the marginal slope in two well-defined channels. Some of the upper channels are small and narrow, and others broad, all brilliantly colored, yellow, orange, red, and rose tints being liberally displayed on

a white ground. It was impossible to obtain the temperature in the central portion of the basin. In the outlet the water had a temperature of 175° F. This was taken on the terraces above the deeper channels, and was of course lower than the actual temperature of the spring. Around the outside of the pit, or caldron, a pile of *débris* composed of broken pieces of geyserite was seen, forming a sort of rim, just as though it had been washed back by an overflow of the spring. This, however, I think is impossible on account of the absence of a wall at the foot of the spring. It is possible that it may be a geyser with long periods, but we have no data to that effect.

Since the above notes were made, this Cliff Caldron has been discovered to be a powerful geyser, to which Mr. P. W. Norris has given the name Excelsior. The following record of its eruptions is taken from the report made by Mr. C. H. Wyman to Mr. P. W. Norris. (See Report of the Superintendent of the Yellowstone National Park, by P. W. Norris, 1881, pp. 54–56.)

Record of the eruptions of the Excelsior Geyser in the Midway Basin, Yellowstone National Park.

Date.	Time of eruption.	Duration of eruption in minutes.	Height of the column of water in feet.	Remarks.
1880.*				
Sept. 27	8.00 a. m.	5	100	Witnessed the last eruption from a distance.
27	3.30 p. m.	7	75	
27	5.30 p. m.	7	100	
27	7.15 p. m.	6	90	
28	9.00 a. m.	5	60	Heavy fog in the morning, clear until sunset, and thence dense mists from the Excelsior Geyser, and fogs from the foaming, hot Fire Hole River.
28	10.30 a. m.	7	75	
28	11.48 a. m.	7	75	
28	3.00 p. m.	5	100	
28	5.20 p. m.	6	100	
28	7.30 p. m.	7	125	
29	9.30 a. m.	7	60	
29	3.30 p. m.	5	60	Heavy snow squalls, shutting off all observation after 7.20 p. m.
29	5.00 p. m.	5	70	
29	7.20 p. m.	7	75	
30	9.00 a. m.	5	50	
30	3.00 p. m.	7	100	Heavy clouds and mists much of the day.
30	5.20 p. m.	5	125	
30	7.15 p. m.	5	75	Mists too dense for observation at night.
30	9.30 p. m.	6	75	
Oct. 1	6.15 a. m.	5	60	
1	8.06 a. m.	10	150	Cloudy and nearly dark all day.
1	10.10 a. m.	15	100	
1	12.55 p. m.	10	200	
1	3.50 p. m.	10	250	
1	5.40 p. m.	10	225	
1	7.10 p. m.	5	75	Too dense fogs and mists to continue observations.
1	9.00 p. m.	5	75	
2	12.15 a. m.	5	75	
2	3.30 a. m.	5	75	Clear, but a very heavy wind down the valley, allowing approach upon the windward side, disclosing the fact that heavy masses of the horizontally-banded wall-rock were fractured and falling into the foaming caldron, which was all that could be observed, save an occasional rock eruption.
2	6.45 a. m.	5	75	
2	8.15 a. m.	5	75	
2	10.10 a. m.	5	75	
2	12.15 p. m.	4	60	

* This is evidently meant for 1881, as the instructions to Mr. Wyman are dated September 27, 1881, and his report is dated October 10, 1881.

CLIFF CALDRON EGERIA SPRINGS

Record of the eruptions of the Excelsior Geyser in the Midway Basin, &c.—Continued.

Date.	Time of eruption.	Duration of eruption in minutes.	Height of the column of water in feet.	Remarks.
1880.*				
Oct. 2	2.15 p. m.	5	50	
2	4 15 p. m.	7	200	
2	5.30 p. m.	5	75	
2	7.00 p. m.	5	50	
2	9.05 p. m.	5	50	
2	11.15 p. m.	5	60	
3	6.30 a. m.	5	100	
3	8.00 a. m.	10	150	Countless rocks, of many pounds weight, hurled like a rocket high above the column of water, some of which fell in and across the river, which is here 100 yards wide, and during much of the day was a foaming flood of hot water.
3	10.10 a. m.	10	300	
3	12.30 p. m.	10	75	
3	3.00 p. m.	10	250	
3	4.30 p. m.	7	75	
3	5.45 p. m.	5	80	
3	7.25 p. m.	6	75	
3	9.20 p. m.	5	75	
3	11.30 p. m.	5	75	
4	6.00 a. m.	5	75	
4	7.30 a. m.	5	75	Broke camp and went to the Upper Basin at 9 a. m.
4	9.00 a. m.	7	75	
4	10.20 a. m.	10	150	
4	11.45 a. m.	5	150	
6	3.00 p. m.	5	75	Returned through mist and snow squalls; weather quite cold.
6	5.25 p. m.	7	100	
6	7.19 p. m.	6	80	
6	9.00 p. m.	7	120	
6	10.40 p. m.	5	75	
7	3.45 a. m.	6	80	Clear and cold, but dense fogs along the river for miles.
7	5.20 a. m.	7	125	
7	6.45 a. m.	5	100	
7	9.08 a. m.	7	120	Left the basin for the Norris Geyser.

*See note on preceding page.

No. 4 is at present probably only a reservoir for surplus water from No. 1, which it is below, and only a short distance away. It is a turbid, blue pool, about twenty feet in diameter, which spreads out into a shallower gray basin, the entire dimensions being 80 by 150 feet. No steam rises from it, and the water is cold.

No. 5 is a light-blue spring, with a white basin about 20 feet in diameter. It receives considerable water from No. 1, and has a temperature of 135° F.

No. 6. *Indigo Spring.*—This is a dark blue boiling spring. It is triangular in shape, measuring 20 by 25 feet. There are several points of ebullition, and the temperature is 196°. The water outlet is lined with lemon-yellow colored deposit. Back of this spring, and south of it, are a number of fissures and steam vents.

No. 7 is a collection of three small bubbling pools: *a* is white lined and bubbles rapidly, but not violently; *b* is an oblong opening in broken fragments of gray geyserite; *c* is a white basin. The temperatures are 169° F., 125° F., and 151° F.

No. 8 is a rapid bubbler, in a white basin 9 by 12 feet.

No. 9 is near No. 8, and is a clear bubbler with two openings; temperature 190°. There are several other small ones near by.

No. 10 indicates the position of two small holes, 6 inches each in diameter, with temperatures of 194° and 195°. The water from them spreads out on a red deposit.

Between the springs 8, 9 and 10 and the river are three crater-like holes in the deposit, at the bottom of which there is a little water. These holes are about 8 feet in diameter.

The springs already described are either on the mound of which No. 1 is the center or on its slopes. Those next to be described are mostly on a broad flat nearer the level of the river.

No. 11 is probably a geyser, although not seen in action by any one as far as I can learn. It has a greenish-gray-brown basin, 22 feet in diameter, in the center of which is a deep cavern-like pool 9 feet in diameter, over which the water has a bluish-green tint. It boils gently and has a temperature of 174° F. The rim is gray and composed of hard geyserite.

No. 12 and 13 do not deserve any mention further than that given in the table. Near them are other small holes not numbered on the map, but none deserve special mention.

No. 14 is a greenish hole 10 by 15 feet, at the head of a large, irregular-shaped, shallow, red basin over which the water spreads. The latter has a rim, and is one of two pools, besides which there are several small holes. The temperature of No. 14 is 105° F.

No. 15 is a basin with two orifices, one of which is red lined and the other white, the former having a temperature of 150° F.

No. 16 is simply a reservoir for water from No. 14. Between it and No. 15 there are numerous small openings, as indicated on the map.

No. 17 belongs to same system as 14–16.

No. 20 has a red, gelatinous deposit, probably viandite. This deposit is found abundantly at various points among these springs.

Nos. 23 to 26 are situated near the river, on the left bank, above the bend, where the valley is narrowing, and are sufficiently described in the table. There are others still above not indicated on the map.

Crossing the river we first met No. 28, which is the upper or most southern spring of the group.

No. 28 is a very handsome blue cavern 25 feet in diameter, and back of it a smaller (5 feet diameter) black, boiling spring (*a*), from which the water flows into No. 28. The water escapes from beneath porch-like masses of deposit and opens directly into the spring below. The temperature is 197°, while in No. 28 it is 183°. The latter therefore is in part at least a reservoir, as is the case with so many of the larger basins.

No. 29 is nearer the river than 28 and has a gray-white basin with a white edge. It is a deep, blue cavern, 25 by 28 feet, and has at one end a deeper hole, which is the spring, and where the temperature is 195° F.

No. 30 is in a pit-like hole 15 to 20 feet deep. The water has a greenish tint, is quiet, and has a temperature of 178° F. The basin is 40 by 50 feet and deep.

No. 31. *Pebble Spring.*—This is a spouting spring, and has a flat basin 6 feet in diameter, which is filled with reddish-brown geyserite pebbles. The water spouts from a hole about 3 inches in diameter, and when seen in action spouted from 6 inches to a foot. The temperature was 191° F.

Nos. 32 and 33 are described in the table. No. 32 is probably the Catfish Geyser illustrated on page 112, in the report for 1871.

No. 34 represents several white-lined holes, which extend under the bed of a small, warm creek. The temperature is 171° F.

No. 35 is a bulging spring at the foot of a bluff of gray deposit, which is stained with iron and perforated by steam vents. The steam escapes from the water in great bubbles. The temperature is 195° F.

No. 38 is a geyser with a circular basin about 30 feet diameter. It is

GENERAL VIEW OF EGERIA SPRINGS

close to the trail and gives constant exhibitions, although the height to which the water is thrown is not great; 20 feet, perhaps, being the maximum.

I saw two eruptions on October 9, separated by an interval of 50 minutes, the first occurring at 1.35 p. m., and the second at 2.25 p. m. On the 11th I saw the following eruptions:

No.	Time of beginning.	Interval.
1	11.30 a. m...	.....
2	1.39 p. m...	.....
3	2.20 p. m...	41 minutes.
4	3.00 p. m...	40 minutes.
5	3.40 p. m...	40 minutes.

The eruptions therefore appear to occur with considerable regularity. They last 6 or 7 minutes, and the average height of the column is not more than 5 feet.

In Plate XIII *a* we have a general view of the plateau of geyserite, on the left bank of the river, upon which most of the springs are situated. The view is from a photograph taken from a point opposite the bend in the river, and looks a little west of north, showing north Twin Butte in the distance. Almost on a line with it, a little to the right, is the Grand Prismatic Spring, indicated by a faint cloud of steam, and still farther to the right is the steam rising from the Cliff Caldron. The position of the other springs will be apparent on comparing the illustration with the accompanying map, on which the springs are indicated by their numbers.

RABBIT BRANCH SPRINGS.

Rabbit Branch is a small hot creek which flows into the Fire Hole at the lower or south end of the Egeria or Halfway Springs. It rises by two branches in ravines east of the Egeria Group and south of the Fifth or White Dome Group. Each of these ravines is the seat of active hot springs. They were not visited in 1871, but were seen in 1872 and 1878. It was my intention to visit them in this latter year, but I was obliged to leave the Lower Basin before the work was completed, and I therefore give the description of the springs given by Professor Bradley in the report for 1872, as he is the only one who has visited them. The springs at the mouth of the creek are included with the Egeria Springs and are shown on the map of that group. The whole stream is lined with warm and hot springs, but there are two principal groups, the northern and the southern.

Northern Group.—The principal one [spring] at the head of the northern fork, a large steaming pool, reaches 148°, and is not surpassed by any of its neighbors. About the forks of the stream a considerable cluster of steam vents, pools, and mud pots give various temperatures up to 186° and 192°; yet, as a whole, the group shows but little activity. Steam vents and small pools run far up the side of the mountain.

Southern Group.—At the head of the southern fork, separated from the last group by from 200 to 300 yards of timber, is a cluster of mostly small springs, which show rather greater activity. The principal vent is situated under the precipitous bank, and is apparently working backward by undermining the overhanging rock. Large masses have already slipped off and fallen into the narrow pool, so as to greatly interfere with the free motion of the water; and, accordingly, though steaming and boiling furiously, it spatters only a short distance. It was impossible to reach the boiling center; the nearest accessible part of the pool gave a temperature of 192°. Crossing the spur to the southward we found instead of a broad flat valley, like the one we had just left, a narrow, steep ravine, partly with precipitous sides, at only one

point of which did we see slight indications of warm springs. There was, however, an abundant flow of cold springs, fully equal in volume to that of the hot springs of Rabbit Branch. As no difference was noticed in the rocks of the two hollows, we could refer their difference in form of erosion only to the solvent power of the hot waters.*

I have included these springs in the Lower Basin although they are separated from it by a ridge of timbered hills and are not shown on the map. Still they belong with the Lower Basin rather than the Upper, and this seems to be the best place for their description.

Recapitulation of springs and geysers of the Lower Geyser Basin.

Name of group.	Number of springs.	Highest temperature.
		° F.
East Fork Sulphur Springs	15 +	193
East Fork Group	95	198½
Butte Group	22 +	180
Camp Group	43	200
Second or Thud Group	15	195
Third or Fountain Group	62	199
Fourth or Fissure Group	55	199
Fifth or White Dome Group	65	201
Sixth or River Group	149	201
Goose Lake Mud Springs	50	.....
Seventh or Fairy Fall Group	56	200
Eighth or Sentinel Group	21	201
Halfway Group or Egeria Springs	45	197
Rabbit Branch Springs	.....	192
Total number of springs	693 +	.....

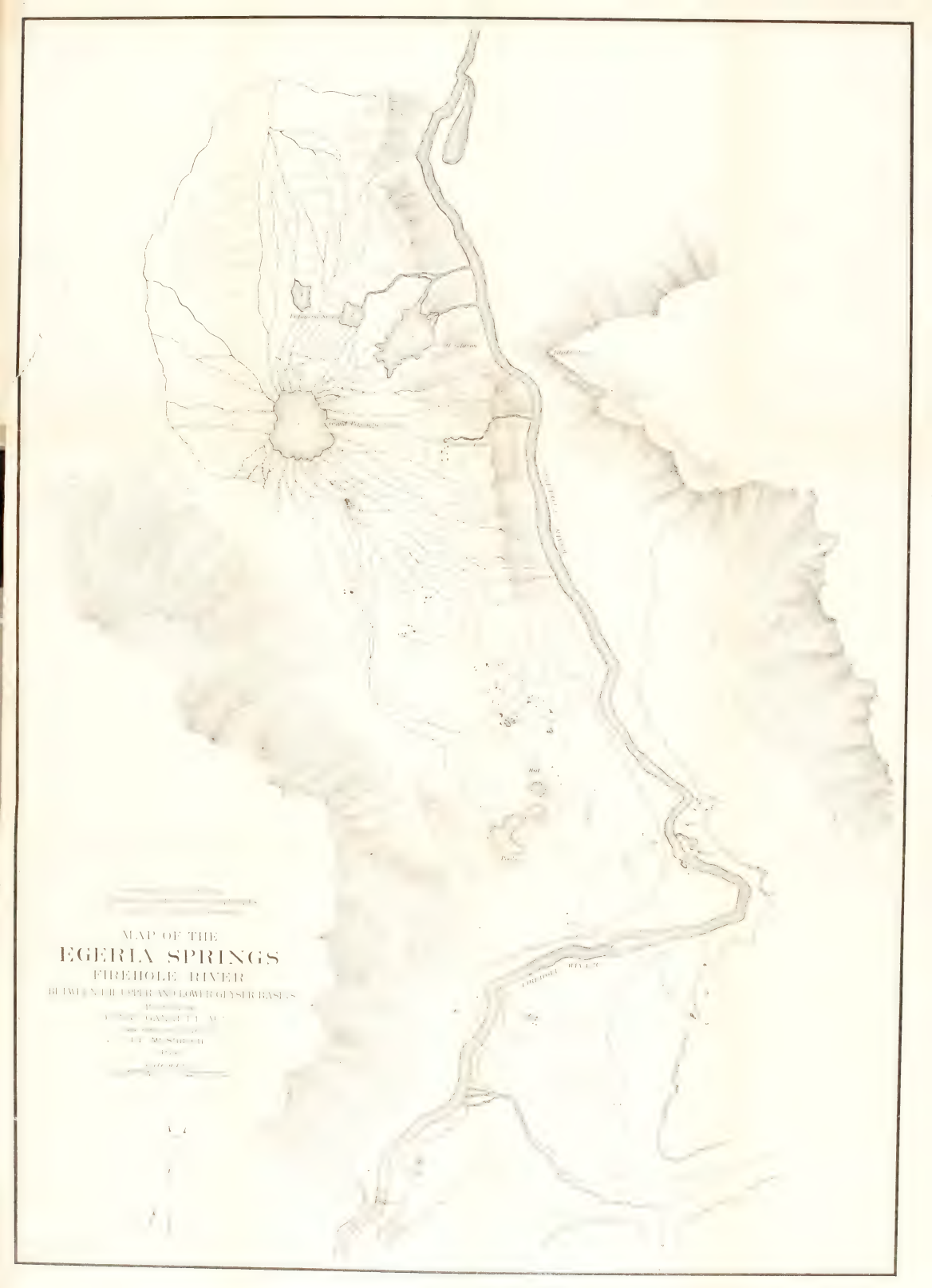
This table just given of course does not give all the springs, but is approximate, representing all the springs actually examined, and the most of those are actually shown on the map of the Lower Geyser Basin.

The following is a list of the geysers of the Lower Basin with the intervals and heights as far as known. The Upper Basin has always presented such attractions to the visitor and the various groups are so isolated from each other that these observations in the Lower Basin are not as complete as is desirable:

Geysers of the Lower Basin.

Name of geyser.	Name of group.	Interval or period.	Duration of the eruptions.	Maximum height.
				Feet.
Fountain	Fountain	About 6 eruptions in 24 hours	17 to 60 minutes	50
Jet	....do	Not known	19 minutes to 2 hours	15
Spasm	....do	....do	Not known	
Clepsydra	....do	....do	....do	30
Fitful	....do	....do	....do	2 to 3
Bead	Fissure	....do	....do	
Pink Cone	....do	....do	....do	
Steady	....do	Constant	....do	30
Young Hopeful	....do	One to two minutes	65 to 80 seconds	15
Great Fountain	White Dome	.....	45 minutes	10
White Dome	....do	Nearly extinct	.....	
Fortress	River	Not known	.....	
Mound	....do	....do	.....	
Rosette	Sentinel	....do	.....	30
Catfish	Egeria Springs	.....	.....	
No. 38 (geyser)	....do	40 to 50 minutes	6 to 7 minutes	20
Excelsior	....do	1 to 4 hours	5 to 10 minutes	300

* Report of the U. S. Geol. Survey for 1872, 1873, p. 239.


MAP OF THE
EGERIA SPRINGS
FIREHOLE RIVER
BETWEEN THE UPPER AND LOWER GEYSER BASINS

CHAPTER VIII.

UPPER GEYSER BASIN OF FIRE HOLE RIVER.

The Upper Geyser Basin of Fire Hole River is the most wonderful of the two, containing as it does the principal geysers whose names are now so well known everywhere. It extends from just below the mouth of the Little Fire Hole River up the main Fire Hole River and Iron Spring Creek, a branch joining the Little Fire Hole just above its mouth. The principal springs and geysers are on the main stream. As the two streams mentioned approach each other as they flow north, the basin is somewhat triangular in shape. The distance from the Soda Geyser Group to Old Faithful Group is about 2¼ miles, and from the latter to the Emerald Group is nearly a mile and a quarter. The entire area of the basin is nearly 4 square miles. The principal geysers are located within a distance of about a mile along the course of the river. The latter flows from southeast to northwest through the basin, and after Iron Spring Creek unites with it the direction is more northerly. The springs appear to add but little to the volume of the river ordinarily, although some of the geysers are said to have largely increased the river during their periods of action. The temperature of the water, however, is affected by the springs, as the observations made in 1872 plainly show. They are the following:

	°F.
Temperature in Fire Hole River above Old Faithful	53
Temperature in Fire Hole River opposite Bee Hive	56
Temperature in Fire Hole River opposite Grand Geyser	60
Temperature in Fire Hole River just above Giant Geyser	60
Temperature in Fire Hole River below Grotto Geyser	60

When the first temperature was taken the air was 56°, and when the last was taken it was 58°.

In the tables and maps of the groups described in this chapter 440 springs and geysers are enumerated, all of which are located by corresponding numbers on the accompanying map. Of these some twenty-six are known to be veritable geysers. The distance from the center of the Lower Geyser Basin to the lower limit of the Upper Basin is about 4 miles, while from the Egeria Springs it is only 2 miles. The trail between the two basins used before the road was cut was very marshy and made the trip a very disagreeable one. The Upper Basin is well timbered, and the soil in most places where there are no spring deposits is composed of the débris of the volcanic rocks, mainly a black volcanic sand. The surrounding rocks are rhyolitic, an obsidian mass being usually seen on the top. The first detailed descriptions of the Upper Basin are those published by the members of the Doane-Washburn expedition, which have already been so frequently referred to, and the names given to the principal geysers are the ones still retained. They, however, did not witness all in action, and the survey in 1871 named some more. In 1878 also we discovered some new geysers, which are now named for the first time in this report.

In the following pages of this chapter the various groups of the Upper

Basin are described, beginning with the Soda Geyser Group, which is the most northern and the first met with on the way up from the Lower Basin.

The best camping place in the Upper Basin is on the south side of the marsh that lies on the west side of the river, opposite the Giantess Group. From here Old Faithful, Bee Hive, Giantess, Trinity, Niobe, Castle, and Grand can all be seen. It was here that we had our station in 1878 for measuring the heights of the columns of water.

SODA GEYSER GROUP.

This name is given to a group of springs, including several small spouters, situated below the mouth of the Little Fire Hole River. The majority of the springs are on the west side, about 15 feet above the river level, although one of the most important is located on the east side at an elevation of about 30 feet above the Fire Hole. These springs were not closely examined in 1878, as our time was devoted to the principal geysers in the main part of the basin.

On the west side the principal geyser is the Soda Geyser, which spouts about every 10 minutes. It was named in 1871 by the topographer, who fancied a resemblance in its jet to the jet of a soda fountain. There are several other small geysers near this, but their periods are not known. In a group of springs west of the Soda Geyser, the following temperatures were taken in 1871: 164° F., 180° F., 194° F. The following were in springs south of the geyser: 140° F., 154° F.

On the east side there is only one that deserves the name of geyser, and this is on the summit of the mound.

Cauliflower Spring.—It is bordered by cauliflower-like forms of greenish-gray geyserite. The water flows from the spring in several small streams, the bed of each one being of a bright orange color. This is probably the spring described as follows by Professor Comstock:

> One of the largest, however, at the summit of the hill has formed a bordering rim at some distance outside of the edge of the original bowl, so as to wall in a large portion of the water, making it, as it were, a shallow pond about the inner cup. This fringing pool is mainly upon the drainage side of the spring, leaving the main bowl nearer the opposite edge.

Professor Comstock mentions seven thermal springs of importance at this place. Temperatures taken here in 1871 were, 146° F., 168° F., 170° F., 180° F., 188° F., 152° F., and 180° F.

RIVER GROUP.

This group includes the springs on both sides of the river, from a short distance above the mouth of the Little Fire Hole to the point where the river bends from its eastern course to a northwest course—a distance of 800 yards. The springs are not definitely separated from those of the Soda Geyser Group on the east side of the river, but may for the purposes of description be considered as a distinct group. There are about seven springs on the left bank, with temperatures of 136° to 190° F. Two of them are spouting springs. On the right bank there are about a dozen springs, several of which are minor geysers. To the upper or southern one we gave the name Restless Geyser, although its periods are not known. The temperatures here range from 138° F. to 188° F. We were obliged to pass these springs hastily, so that sufficient data to catalogue them were not obtained. Some of

the springs are handsome, and one curious fact is the existence of several bowls of different temperatures in close connection with each other.

CASCADE GROUP.

Under this head I include a few springs that are in the bend of the Fire Hole River west of the cascades. One spring or geyser on the east side also may be included. The latter was named Sentinel Geyser by Colonel Barlow in 1871. He says:

> Here, on either side of the river, are two lively geysers, called the Sentinels. The one on the left [east] is in constant agitation, its waters revolving horizontally with great violence, and occasionally spouting upward to the height of 20 feet. Enormous masses of steam are ejected. The crater of this geyser is 3 feet by 10. The opposite Sentinel is not so constantly active and is smaller.*

The latter is seen in Plate 15, the distant column of steam showing its location. The springs on the western side of the river are separated from the springs of the Grotto Group by a low hill. They are some ten in number, and have temperatures from 170° F. to 192°; some are boilers, and others are quiet. The principal spring is the Cyclops Spring, which is a magnificent spring 50 by 60 feet, and of great depth. It has a temperature of 170° F.

GROTTO GROUP.

Under this head I have included all the springs in the neighborhood of the Grotto Geyser, on both sides of the river. They occupy an area of about 800 square yards, and have among them two first-class geysers. The springs are, with the exception of No. 17, not remarkable for beauty, nor of any special interest. The mound on which they are situated is partially overgrown with trees, which separate the majority of the springs from the cones of the Grotto Geyser. Our time for the examination of the group was small, and we were unable to devote any time to the observation of the geysers. The latter are not in sight from the other parts of the basin, and the facts presented are therefore small as compared with those given in the descriptions of the other groups. The table presents most of the facts noted in the case of the springs, and from the description there given the different springs can be recognized.

Table of the Grotto Group.

Number or name.	Size and depth.	Temperature.		Remarks.
1	Basin 28 feet diameter	*a* 180		Two openings in one basin; *a* is double.
	a 3 by 5 feet	*b* 175		
	b 3 feet diameter			
2. Grotto Geyser	Large cone 8 feet high, orifice 2 by 6 feet and 19 feet deep.	198°		See text for full description.
	Small cone is 4 feet high, orifice 3 by 5 feet, 16 feet deep.	196°		
3	19 by 9 to 17 feet	†198		Inky-green pool constantly boiling at one end. It is a pulsating spring.
4	6 by 7 feet	190		Almost constant bubbler, with considerable overflow.
5	Orifice 18 inches by 1 foot.	133		Hole in the water outlet of the grotto from which it receives water.

*Reconnaissance of the Yellowstone River, 1871, p. 25.
†14 feet below the surface it is 199°.

Table of the Grotto Group—Continuen.

Number or name.	Size and depth.	Temperature.		Remarks.
6	Basin 16 feet diameter, in which is a fissure 2 by 4 feet.	176	.....	Water is 2 feet below the top.
7	15 by 20 feet	175	.....	Light-blue funnel spring.
8	Crater 4 by 3 feet, fissure at base.			These springs are in a basin of hard geyserite, and at times are connected probably after an eruption of the grotto, which sends water to No. 7.
9	13 by 14 feet	149	.....	Yellowish basin with green center, red line around the outside.
10	*a* 7 by 11 feet *b* 7 by 9 feet *c* 9 by 10 feet	*a*140	.....	Red bordered springs near 9. They have greenish-yellow basins; *c* bubbles slightly.
11	Basin 30 feet diameter in outside measurement. Water fills 11 by 18 feet, 7 feet deep.	177	.....	Double funnel in bluish-gray basin.
12	7½ by 8½ feet, 3 feet deep	154	.....	Yellow-lined spring with deep-red border.
13	9½ by 10 feet	179	.....	White bubbler with gray border, yellow and red edge.
14	10 by 18 feet	160	.....	Spring with two central basins.
15	3 by 8½ feet	162	.....	Near No. 14.
16	19 by 20 feet	183	.....	Blue-gray basin; near it are three small, circular pools.
17. Bottomless Pit	Total length is about 181 feet, width varies. *a* 40 by 45 feet *b* 35 by 49 feet *c* 25 by 34 feet *d* is 10 feet wide. *e* is 34 by 53 feet.	*a*120 *b*150 *c*153 *d*165 *e*184	.....	*a* is a red-lined spring with moss-like basin. *b* reddish-yellow basin with fissure in center. *c* yellow-green pool. *d* greenish-yellow. *e* deep-blue, cavern-like spring. These are all connected with each other.
18	17 feet diameter, 10 feet deep.	184	.....	This spring is on the east bank of the river below the Fan Geyser.
19	20 by 30 feet	174°	.....	
20. Perpetual Spouter.	.....	.....	.....	This is a steam vent on the mound with the crater of the Fan Geyser.
21. Fan Geyser	.....	.....	.....	See the context for the full description.
22. Riverside Geyser.	.....	.....	.....	Do.

All the springs enumerated in this table are not numbered on the map, as I was obliged to work at a different time from Mr. Mushback, who plotted them, and after returning from the field I could not identify all with certainty, and I therefore placed only the numbers of those I knew to be correct on the map.

DESCRIPTION.

No. 1. This spring is between the Giant and Grotto Groups, and might be included with the former as well as latter if placed according to its location. It is a large basin, surrounded by beaded silica, and has two openings, which appear like two separate springs when the water is low, as it was when examined. There is also a small hole near *a*.

No. 2. *Grotto Geyser* (Plates XIV and XIV*a*).—This interesting geyser received its name in 1870 from the peculiar shape of the main or larger crater, which is hollowed into fantastic arches, beneath which are grotto-like cavities that act as lateral orifices for the escape of water during an eruption. This crater, which we will call Cone No. 1, is very irregular, and is 8 feet high. The orifice is 2 by 6 feet and 19 feet in depth. On the north side of the orifice there rises a curious pillar-like mass of geyserite. It is somewhat club-shaped, and is about 6 feet in height.

Cone No. 2 is 19 feet in diameter at the base and 14 feet on top. It is 4 feet in height, and has a quadrangular orifice measuring 3 by 5 feet, in which the water during quiescence is from 10 to 15 feet below the top. The basin is 16 feet in depth. On the east side there is a slight depression in the rim. The entire length of the mound, including the two cones, is 53 feet, and the width is 26 feet; the centers of the two cones are 30 feet apart. The space between them is raised above the general level, and covered with beaded silica, in which there are two small vents that spout during the action of the two large cones. Plate XIV is a view of Cone No. 1 from the west, while in Plate XIV*a* both the cones are shown, the view being from the east or river side.

The white and grayish-white geyserite, of which the cones and mound are composed, is brittle and breaks readily into slab-like masses. Pools of water are found on the west side of the geyser and on the main cone near the pillar-like mass. The eruptions consist of two well-defined columns, alternating with each other, from the two cones, and spurts from the small vents. A large portion of the water is thrown into spray, which adds to the effect. The water escapes in jets, which average about twenty per minute.

1870.—The Grotto is mentioned by Langford as spouting to a height of 60 feet, the eruption lasting an hour.*

1871.—I did not see the Grotto in action, but Colonel Barlow speaks of its playing several times in the twenty-four hours.†

1872.—The following eruptions were noted by me in 1872:

No.	Date.	Eruption began.	Duration.	Maximum height.	Average height.
			h. m.		
1	Aug. 16	2.45 p. m	0 38	Cone 1, 32 feet Cone 2, 24 feet	Cone 1, 13 feet. Cone 2, 8 feet.
2	Aug. 19	1.27 p. m	2 33	Cone 1, 31 feet Cone 2, 41 feet	Cone 1, 16 feet. Cone 2, 13 feet.

In the second eruption the maximum was attained, in Cone No. 1, 1 hour and 13½ minutes after the eruption began, and in Cone No. 2, 2 minutes later. After the eruption the water sank rapidly until it was out of sight, and everything became perfectly quiet. In the second eruption the maximum height of Cone No. 2 exceeded that of Cone No. 1, and the spurt made a fine display, the base of the column being wide, tapering to a point at the top. It was accompanied by considerable steam. In Cone No. 1 the average height was very uniform, and the mass of water thrown up was very much spread out. The eruptions have a steam period at the close. In the first eruption this was about 3 minutes; in the last one it was not taken, but it was short.

In an eruption seen by Mr. Holmes, but not noted, the smaller cone spurted higher than No. 1, although usually the reverse is the case.

* Scribner's Monthly, Vol. II, p. 124.

† Reconnaissance of the Yellowstone River in 1871, p. 26.

1873.—Professor Comstock describes one eruption as follows:

We witnessed but one eruption, which began at 2.17 p. m., August 25, continuing uninterruptedly till 3.03 p. m., when it ceased altogether. The water was ejected with much force in two irregularly-alternating columns, proceeding from the two large, conical chimneys of which the mound is made up and from several intermediate openings of small size. The volume of water and vapor was large, and a good-sized stream was formed by the surplus, which ran off down the hill to the river.* The maximum height was nearly 25 feet.

1875.—Captain Ludlow says† the Grotto played whenever he was near it, and gives the height as 20 or 25 feet. Grinnell and Dana, in the same report, say the Grotto was almost continuously active during their stay.

1877.—General Sherman says that during their stay, in 1877, the Grotto was repeatedly in agitation, but the jets did not exceed 20 feet.

1878.—I witnessed only two eruptions on the afternoon of September 11. They were separated by an interval of 2 hours 26½ minutes. The duration was not ascertained nor was the height ascertained, but it was not over about 20 feet in each case. A very small portion of the time we were in the Upper Basin was devoted to the Grotto, and we did not, therefore, obtain any data as to its periods. The following temperatures were taken: Cone No. 1, 198° F.; cone No. 2, 193° F.

The duration of the three eruptions that have been noted above are: 38 minutes, 2 hours 33 minutes, 46 minutes, which are so different that very little can be determined from them. It is probable that the Grotto has a double set of eruptions.

Springs 3 and 4 are east of the Grotto at a little lower level.

Nos. 6, 7, and 8 are in one basin and at times evidently connect, probably when the overflow from the Grotto is large, as the channel leading from the geyser carries the water directly into No. 7. The basin is of hard, grayish geyserite. The three bowls are sufficiently described in the table. The temperatures are low, indicating that the springs are to a certain extent reservoirs.

No. 17. This is really a series of bowls or basins connected by channels, the rim being continuous around the entire basin, which has a total length of about 181 feet. *a* is a quiet spring that is now probably nearly extinct. It is lined with tuft-like mossy-looking masses. *e* is a beautiful blue cavern-like spring of great depth, and was named by one of the members of the party, who called it "the bottomless pit." The following is the comparison of the temperatures in this spring, taken in 1871 and in 1878:

Basin.	1871.	1878.
	°F.	°F.
a	168	120
b	150	150
c	Not taken.	153
d	166	165
e	150	184

From this table it is probable that *e* has periods of activity which increase the temperature. *a* appears to have decreased in temperature since 1871, which the character of the basin also indicates. The other two springs, *b* and *d*, remain about the same.

The rest of the springs on the west side of the river do not deserve

* Reconnaissance of N. W. Wyoming by Capt. W. A. Jones, in 1873, pp. 251–252.

† Reconnaissance from Carroll, M. T., to Yellowstone National Park, and return, in 1875, p. 25.

GROTTO GEYSER IN ACTION. UPPER FIRE HOLE BASIN

urther mention than is made in the table. Crossing to the east side e find two geysers, viz., the Fan and the Riverside.

No. 21. *Fan Geyser* (Plate XV).—The Fan Geyser was so named by ie party of 1870 because the water during the eruption spreads out in in-shaped jets, from the fact that there are two craters, the streams om which cross each other. These two craters have orifices of about feet diameter each, and just below them is a steam vent called the perpetual spouter," which sometimes acts in concert with the Fan. he crater of the geyser is composed of pink geyserite, which rises from ie river in a series of rounded masses which are beaded with silica.

1870.—Langford describes the eruption of the Fan as follows:

The Fan has an orifice which discharges two radiating jets of water to the height 60 feet, the falling drops and spray resembling a feather fan. It is very beautiful. s eruptions are very frequent, lasting usually from 10 to 30 minutes. A vent con-ected with it, about 40 feet distant, expels dense masses of vapor 50 or 60 feet high, ccompanied by loud, sharp reports during the time the geyser is in action.*

Lieutenant Doane, speaking of the same geyser, says:

First, the steam would rush from the upper crater, roaring violently, then this ould suddenly cease, to be followed by a fan-like jet of water rising from the lower rater to the height of over 40 feet, often playing for perhaps two minutes; then this ould suddenly stop flowing, and the steam would rush forth again for a time. Oc-asionally the small crater threw a transverse stream, sometimes alternating with ither of the others; and thus they played on for hours, after which all would sub-ide to a gentle bubbling.†

1871.—I did not see the Fan in action in 1871, nor were any notes oncerning it obtained by the other members of the party.

1872.—I did not see the Fan in action in 1872, but Professor Bradley id, and has the following:

When Fan Geyser was in full eruption its partner, 30 yards off, was steaming ently. Fan stopped for a moment, and its partner fairly roared with a rush of steam, hich stopped as soon as Fan opened again. Yet they are not in full sympathy; for n another occasion Fan was steaming or boiling very gently, while its partner was oiling furiously and throwing water 5 or 10 feet high, but with quiet intervals, dur-ng which Fan showed no access of force. (Under such circumstances, one is inclined o question whether Fan's partner may not possibly serve as the vent for two distinct eyser-tubes.)‡

These notes were taken mainly for the purpose of determining the mpathy, and do not give any facts as regards the interval or duration.

1873.—Professor Comstock saw the Fan in action and describes the ruption as follows:

This began at 2.43 p. m., almost precisely at the moment when the eruption began the Riverside. Gradually increasing in intensity, it was throwing a large column of ater at 2.49 p. m., which continued, but gradually diminishing, until 2.45 p. m., at hich time it almost ceased, spluttering occasionally, however, until 2.56 p. m. This ecord shows a remarkable similarity or sympathy between the Fan and the Riverside.

1877.—General Sherman's party saw the Fan in action, but give no articulars.

1878.—I saw but one eruption of the Fan, which occurred September 1. The following are the notes:

First spurt at 12.13 p. m.; stopped suddenly in 2 minutes 10 seconds.

Second spurt at $12^h.\ 15^m.\ 40^s$ p. m.; stopped at the end of 2 minutes 5 seconds.

Third spurt at $12^h.\ 18^m.\ 35^s$ p. m.; stopped at the end of 25 seconds.

*Scribner's Monthly, Vol. II., 1871, p. 123.
†Yellowstone Expedition of 1870, p. 31.
‡Report U. S. Geol. Survey of the Terr., 1872, p. 236.

Fourth spurt at 12h. 20m.30s p. m.; stopped at the end of 2 minutes 10 seconds.

The intervals of quiet are 30 seconds, 30 seconds, and 1 minute 30 seconds. After this the steam escaped gently.

The third period the height reached was not very great, but on the fourth it was high. None of the spurts, however, were accurately measured. Only one orifice spouted. The one farthest from the river gave off a slight amount of steam but no water, and the "perpetual spouter" steamed during the entire eruption. The column was not perpendicular but slanted toward the river. The amount of water ejected was slight and was largely broken into spray. The Riverside was quiet during the action.

The following shows the comparison of the different years:

Langford, 1870—10 to 30 minutes in duration.

Comstock, 1873—13 minutes in duration.

Peale, 1878—9 minutes in duration.

No. 22. *Riverside Geyser.*—This double geyser received its name in 1871. It does not appear to have been seen in action in 1870. It is 450 feet above (south of) the Fan, on the same side of the river, just above the bend. It has a low, irregular mound with a chimney in the center. It has two orifices and spouts at intervals that are undetermined, the column reaching a height of 80 to 90 feet, as estimated in 1871. It is somewhat out of the way, and unless seen in action would not be taken for a geyser of any importance, as there is little about its crater to attract attention.

In 1873 Professor Comstock saw it in action, and describes the eruption as follows:

> A little below the grotto, across the river, a geyser which is situated near the edge of the stream began to spout at 2.43 p. m. This is known as the Riverside Geyser. A jet of fine spray was very suddenly thrown more than 30 feet into the air, which continued quite steadily until 2.47.5 p. m., when it ceased acting for one-half minute; then it played weakly for 2 minutes, ceasing again for half a minute; then played again rather vigorously until 2.53 p. m. (2½ minutes). At 2.45 p. m. it roared loudly and became quiet at 2.56 p. m., after which no action occurred.

The duration of this eruption was 13 minutes. The simultaneous action with the Fan was probably only a coincidence, as during the eruption of the latter, seen by myself in 1878, the Riverside was quiet.

In 1877 General Sherman's party saw the Riverside in action once,* and Colonel Poe says "it astonished us by the duration of its eruption, which was more than 10 minutes."†

GIANT GROUP.

Although this group is small as compared with the other groups of the basin, it contains two first-class geysers, and one minor geyser that has a cone of considerable beauty. There are three clusters of springs, the principal one being on the platform of the Giant Geyser, the second on the platform of the Oblong Geyser, and the third on the opposite side of the river. The latter is separated from the Grand Group by a narrow strip of timber, or it might be included with the latter.

The springs are sufficiently described in the table which follows, but the geysers deserve special mention, which will be given after the table. Temperatures taken in the cluster on the east side of the river in 1871 were 172° F. to 196° F. Temperatures on the platform with the Giant, taken in 1872, ranged from 182° F. to 196° F. In the Giant the same

* Reports of inspection made in the summer of 1877, &c., page 36.

† *Ibid.*, page 78.

FAN GEYSER, UPPER DEEP HOLE BASIN

year a temperature of 194° F. was obtained, which corresponds with that obtained this year. It is difficult to get the temperature, as the geyser is usually in violent agitation.

Besides the springs on the platform of the Giant enumerated in the table there are many vents (15 to 20 in all).

Table of the Giant Group.

No. and name.	Size and depth.	Temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1. Giant	Cone 10 feet high, 24 by 25 feet at base, 5 by 8 feet at top orifice; is about 5 feet in diameter; 25 feet deep.	198 at 13 feet below level of platform; 194 at surface.	11.15 a. m.	58	For complete description see text following the table.
2		177 at the surface; 199 at 11 feet below the surface.			Depressed craters.
3		191 at the surface; 196 at 9 feet below the top.			
4. Young Faithful		197 at the surface; 200 at 13 feet below the surface.			Spouts every few minutes, throwing the water in spurts to 5 or 10 feet.
5	Fissure 3½ feet long				
6. Oblong Geyser.	50 by 21 and 31 feet	195; 8 feet below the surface the temperature is 196.			On a platform of geyserite near the river.
7	Cone				This small cone has several openings and 2 other cones near it.
8	25 by 48 feet; 14 feet deep.	*a.* Surface, 194			*a* is a bulger.
		b. 13 feet below the surface, 175.			*b* is a pool.
9	14 by 30 feet; 9 feet in depth.	Surface, 186; 8 feet below surface, 195.			Inky-tinted boiling pool.
10	16 by 17 feet	198			Constant boiler.

No. 1. *Giant Geyser* (Plate XVI).—The Giant was named in 1870 by the Washburn party, N. P. Langford first publishing the name in Scribner's Monthly, in 1871. Although rarely seen in action it well deserves its name. It is readily recognized from its peculiar crater, which has been compared to a broken horn, but, as Stanley* says, it is more like the stump of a hollow sycamore tree of gigantic proportions, the top of which has been torn off by a storm.

It swells out irregularly at the base, just like the roots of a huge tree; the grayish silica crust represents the bark of the sycamore, while the cavity is carved into numerous little grooves, and stained with various minerals, giving it a dark coating, reminding you of the decayed part of the inside of an old stump.

This curious crater is broken down on one side, as though it had been torn away during an eruption of more than ordinary force. On this side one can look into the crater if he can manage to avoid the jets which are being continually spurted from it.

The crater is dark-colored, lined with tawny-yellow, and rises 10 feet above the platform. At the base it measures 24 feet by 25 feet, which diminishes to 8 feet at the top. The platform, or terrace, on which it is situated has a circumference of 342 yards, and rises four feet above the general level. It is composed of laminæ of geyserite, which are well

*Rambles in Wonderland, p. 114.

exposed on the river side, where they have been cut into by the water. These layers are irregular in composition and very hard, especially in the lower ones, which are the older. From these the specimens of *pealite* described in the report for 1872* were obtained. In some of the shallow pools near the crater, smooth pebbles of various shapes are found, as in the pools surrounding other geysers. The depth of the crater, as ascertained by dropping a line into it, was 25 feet.

1870.—Langford, describing the eruption witnessed by the Washburn party, says:

> The Giant discharged a vast body of water, and the only time we saw it in eruption, the flow of water, in a column 5 feet in diameter and 140 feet in vertical height, continued, uninterruptedly, for nearly three hours.†

Doane gives the time as 3½ hours.‡

1871.—During our stay in the Upper Basin, in 1871, no eruption of the Giant occurred, but Mr. Jackson, who was in the basin longer, saw it in action. The eruption he saw is the one described by Colonel Barlow.§ He says:

> It throws a column of water the size of the opening to the measured altitude of 130 feet, and continues the display for an hour and a half. The amount of water discharged was immense—about equal in quantity to that in the river—the volume of which during the eruption was doubled. But one eruption of this geyser was observed; its periodic times were not, therefore, determined.

Colonel Barlow does not give the date of this eruption, but it was on either the 6th or 7th of August, for we left the basin on the morning of the 6th, and he followed us on the morning of the 8th.

1872.—The Giant was not seen in eruption during the three days I was in the Upper Basin. When visited it was found boiling, vigorously spurting at times above the top of the crater. There appeared to be periods of increased activity, when some of the smaller vents became quiet. This fact was also observed by Professor Bradley, who says:‖

> When the two large vents [Giant and Young Faithful] began to show activity, though boiling to only small elevations, these little ones became quiet.

The question of sympathy between these vents and the geysers cannot, however, be definitely determined, upon the limited data obtained up to the present time.

1873.—Edwin J. Stanley witnessed an eruption of the Giant, and describes it graphically as follows:¶

> The first thing I observed when it gave signs of action was the cessation of the little steam-jet, when the geyser nearest it began to surge at a fearful rate, throwing a great volume of water to an altitude of 20 or 30 feet. It played but a moment, and the next one went through a similar operation, when, as if ashamed of their significant failures to rise in the world, or in honor of the grand chief of the realm who was about to appear, they all retired from the scene of action and became quiescent. Then, with a terrible rushing and rumbling below, with a powerful effort and fearful heavings that caused the very earth to groan, and seemed sufficient to tear the solid walls of the crater into a thousand atoms the Giant came forth in the majesty of his mighty power. A volume of boiling water, the size of the nozzle of the crater, was projected to a great altitude, the action being repeated several times. Then for a moment all was quiet. Thinking it only a feint, we attempted to approach the orifice and make investigations, when we were met by an immense volume of steaming water, as if just from one of Hecate's caldrons, causing another disorderly retreat. It now commenced in earnest, and we surely witnessed one of the grandest displays of water-works ever beheld by mortal eyes. The foundations of the great deep seemed literally to have been

* Page 153.
† Scribner's Monthly, Vol. II, 1871, p. 124.
‡ Yellowstone Expedition of 1870, p. 31.
§ Reconnaissance of the Yellowstone River, p. 26.
‖ Report of U. S. Geol. Survey for 1872, 1873, p. 236.
¶ Rambles in Wonderland, New York, 1878, pp. 114–115.

broken up and turned loose again upon our sinful world. A steady column of water, graceful, majestic, and vertical, except as swayed by the passing breezes, was by rapid and successive impulses impelled upward above the steam until reaching the marvelous height of more than 200 feet. At first it appeared to labor in raising the immense volume, which seemed loath to start on its heavenward tour, but it was with perfect ease that the stupendous column was held to its place, the water breaking into jets and returning in glittering showers to the basin. The steam ascended in dense volumes for thousands of feet, when it was freighted upon the wings of the wind and borne away in clouds. The fearful rumble and confusion attending it were as the sound of distant artillery, the rushing of many horses to battle, or the roar of a fearful tornado. It commenced to act at 2 p. m., and continued for an hour and a half, the latter part of which it emitted little else but steam rushing upward from its chambers below, of which, if controlled, there is enough to run an engine of wonderful power. I advanced and stood near enough on the windward side to cast large masses of silica into the ascending volume, which were hurled with force many feet into the air. The waving to and fro of such a gigantic fountain when the column is at its highest—

"Tinseled o'er in robes of varying hues."

and glistening in the bright sunlight, which adorns it with the glowing colors of many a gorgeous rainbow, affords a spectacle so wonderful and grandly magnificent, so overwhelming to the mind, that the ablest attempt at description gives the reader who has never witnessed such a display but a feeble idea of its glory. Our entire party were perfectly wild with enthusiasm. We could not suppress emotion, but shouted and cheered till out of breath, and some fired revolvers and guns in the air, so great was their excitement in the midst of such a display. Every person in the basin—thirty-four in number—was soon on the ground, and lawyers, judges, professors, farmers, merchants, miners, and philosophers, were all alike filled with enthusiasm by the magnificent spectacle. A perfect river of water, equal to the volume of the Fire Hole, rushed down the slope; and in our excitement to get a view from every point of vision, we several times slightly tested its temperature by a misstep, landing us half-way to our boot-tops in the steaming flood. Every one thought the column 250 feet high, though we had no means of measuring it.

He does not mention the date on which this occurred, but it was either the last of August or the early part of September, for on page 90 he says: "Next day, August 29, we were to arrive at the real Geyser land."

Professor Comstock left the Upper Basin for Yellowstone Lake August 26, so that he did not see this eruption. During the time he was in the basin "the action was constant, the water being rarely thrown in successive jets to a height of 3 feet or less above the summit of the encircling wall, but as a rule the column did not rise sufficiently to throw the liquid over the edges."*

1874.—The Earl of Dunraven, in his "Great Divide" (p. 273), says:

I was fortunate enough to see the Giant play, but I was not sufficiently near to form anything like an accurate estimate of the quantity of water cast up, or of the height to which it was thrown. The volume of water appeared immense, and huge clouds of steam arose from it. The eruption lasted only a few minutes; which is strange, as Professor Hayden describes it as playing for an hour and twenty minutes, and throwing a column of water to a height of 140 feet.

Although I cannot say so positively, yet I am of the opinion that the eruption seen by Dunraven was not of the Giant, but of the Oblong Geyser. The description and the duration agree better with the action of the Oblong; and if, as his notes seem to show, he was at a distance he might easily have made the mistake, as the two are near each other, and in 1878 we thought, on several occasions, that the Giant was in action, but discovered afterwards that it was the Oblong. The two being on a line, as seen from the upper portions of the basin, was the cause of the mistake on our part, and I suspect the same mistake was made by him, especially as he was probably not aware of the existence of the Oblong Geyser.

1875.—Dana & Grinnell say (p. 132 of Ludlow's Report): "The Giant was quiet, occasional spurts of water to the top of the crater being the only sign of latent energy."

* Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, in 1873, p. 251.

1877.—The geyser was not, so far as known, seen in action during this season.

1878.—The geyser was visited a number of times during our stay in the Basin, and always found boiling vigorously, with occasional spurts or jets which reached above the top of the cone. It was not seen in action by any member of our party. Its period is evidently a long one. The following temperatures were taken: Surface, 194° F. to 198° F.; 13 feet below the platform level, 198° F. It was difficult to keep the pole carrying the thermometer in the water, as the spurts were projected with great vigor from the orifice of the geyser. The platform and cone presented the same appearance as in 1872.*

No. 4. *Young Faithful Geyser.*—This geyser is on the platform with the Giant. I do not know where or how it obtained the name, but it is so called in Dunraven's Great Divide; and as this designation is the only one it has had, as far as I can learn, I have retained it. It has a mound of beautifully beaded geyserite, rising 6 feet above the level of the platform, or terrace, and having a circumference of 232 feet at the base. On the summit of this mound are two orifices, or basins. The first measures 2½ feet by 6 feet, and at the bottom are two holes from which the water is projected simultaneously. The greatest depth reached in this with the line was 17½ feet.

The second orifice, or basin, is 3 feet higher than the first, and is a foot in diameter and 12 feet in depth.

This geyser acts somewhat continuously, with irregular spurts from 10 feet to 20 feet. It is probable, judging from the deposits about it, that it has periods of action that would place it among the important geysers. Its behavior during the eruptions of the Giant have not been noted. The temperatures taken this year are as follows: Surface, 197° F.; 13 feet below the surface in orifice No. 1, 200° F. The temperature in this geyser had never been taken before, on account of the violent spurting of the water from it.

No. 6. *Oblong Geyser* (Plate XVII).—This handsome basin was thought to be merely a hot boiling spring in 1871, but in 1872, when it received its name, it was suspected to be a geyser, although not seen in action. It has never before been described, although it figured in the report for 1872 (p. 155). It is an oblong pool 50 feet in length by 31 feet wide at the end nearest the river, and 21 feet at the opposite end. At the bottom are two large cavern-like bowls that are of great depth and over which the water appears of a deep greenish-blue tint. The ridge, or platform, separating these two bowls is 7 feet below the surface of the water. The bowl nearest the river end is the largest and deepest. The rim of the geyser is raised from 2 to 6 inches and is elaborately ornamented with large, white, globular masses of geyserite, somewhat like those in the crater of the Turban Geyser, only more numerous and more regular. Outside of these is a layer or rim about 2 inches high, which has an appearance as though it had been cut out by a die, so clearly defined and regular is it. The basin thus described is on the summit of a broad platform (about 250 by 150 feet), which is about 5 feet above the level of the river. The water boils in the center, and when examined on the morning of September 11, 1878, had a temperature of 195° F. at the surface and 196° F. below the surface. The overflow passes off from the center of the south side of the basin, flowing into a series of shallow basins ornamented like the main spring, on a diminutive scale. They are gray and yellow in color. Similar basins

*In the Report of the Superintendent of the Park for 1881, page 57, an eruption of the Giant is noted as occurring on Oct. 5, 1881, at 8 p. m., lasting 25 minutes, the column reaching 250 feet in height, accompanied by terrific earth-trembling.

CRATER OF OBLONG GEYSER. UPPER [illegible]

are seen on the north side also, but here instead of receiving the overflow they hold the water that falls during the eruptions. The eruptions are very fine, and resemble in some respects those of the Giantess, although the duration is only a few minutes. The whole mass of water in the basin appears to be tossed into the air in an immense splashing mass, with an immense escape of steam, through which occasional jets are projected to a height of 30 or 40 feet. Several eruptions were seen from a distance while we were in the Upper Basin, from August 27 to September 1, but they were not identified at the time and no observations were made. On our second visit the following were noted:

No. 1.—Eruption began at 5 p. m., September 10; duration, 6 minutes.

No. 2.—Eruption began at 1.15 p. m., September 11.

The notes are of course too few to determine anything in regard to the periods of the geyser, but the interval is probably not of very great length, as clouds of steam were seen rising from the position of this geyser almost every day of our first visit to the Basin. As I have already indicated, I think it probable that the supposed eruption of the Giant, seen by the Earl of Dunraven, was of this geyser instead. It is not strange that it escaped notice in previous years, as the Basin is so large that one is working in the upper part he necessarily misses seeing the geysers in the lower part. Our stay in 1871 and 1872 was limited also, as was that of Doane in 1870 and Comstock in 1873.

ROUND SPRING GROUP.

This name, for convenience, has been given to a small cluster of springs that are situated between the White Pyramid Group and the river, opposite the lower or northern cluster of the Grand Group. The name is given because the prevalent form is circular, seven out of the nine springs having large, flat, circular basins. But two of the springs have high temperatures, one of which (No. 7) is a small spouter and the other (No. 9) a vigorous boiling spring. Three temperatures taken in this group in 1871 are, 148° F., 154° F., and 156° F., which is about the same as shown in the table. There are probably no true geysers in the group, as the deposits surrounding the springs do not indicate the falling of the water from any great height. The springs are all sufficiently described in the following table:

Table of the Round Spring Group.

Number or name.	Size of spring.	Temperatures.	Remarks.
		° F.	
1	26 by 31 feet	146	Red and green lined pool. The water does not fill the basin.
2	Basin is 38 by 46 feet. Spring in center is 15 by 16 feet.	150	
3. Round Spring	18 feet diameter, orifice 3 feet diameter.	164	Yellow-lined flat basin; with funnel-shaped orifice.
4. Pear Spring	37½ by 10 feet and 21 feet	159	Double white-lined basin; water has greenish-white tint.
5	52 feet diameter	146	Outside basin is gray; inner one is greenish-yellow.
6	*a* 6½ feet diameter	*a* 164	Two basins with small orifices.
7	*b* 2 feet diameter	*b* 146	
8	Basin is 8 feet diameter spring 3 feet diameter.	180	Spouting spring.
9	Basin 19 feet diameter; spring is 7 by 7½ feet.	144	Basin not full. The spring has a small fissure in the center.
10	3½ by 6 feet	196	Clear boiling spring in a white basin.

WHITE PYRAMID GROUP.

This group is 400 or 500 feet back of the Round Spring Group, at a little higher level, being about 50 feet above the level of the river. We succeeded in getting all the springs of this group mapped, but were ordered to the Lower Geyser Basin before the temperatures of all were taken. The group is named from the white pyramid which stands back of the springs and forms a prominent landmark in this portion of the basin.

The Punch Bowl has been included in the group, although it is some distance from the rest of the springs. Its drainage, however, joins that from the other springs and goes with it past the white pyramid.

Springs 1–8 form the principal cluster. West of them are four springs, with spongy mounds, in a marsh; they are not enumerated in the table.

Springs 9–11 are in the midst of a number of bubbling holes. I have called the cluster "The Bubblers."

Table of the White Pyramid Group.

Number and name.	Size and depth.	Temperatures.	Remarks.
		°F.	
1	9 feet diameter	162	Turbid spring in grass, under a log.
2	Basin 20 by 25 feet; *a* is 7 by 5 feet, *b* is 8 feet wide.	*a* 146 *b* 150*	Two openings in one basin.
3	3 feet diameter	185	Small spouter.
4	Has a large platform of deposit.	*a* 195 *b* 190	*a* is a long gray pool extending under a fissure over which is a platform with hole *b*. Outside is basin *c*.
5. Spray Geyser	Geyser cone 2½ feet high, 19 feet long by 7 feet wide; basin is 15 feet long.	199	Boils violently at one end.
6	12 feet deep	165†	Beautiful white and blue basin.
7. Comet Geyser	Mound 18 inches high and 3 feet diameter, with another only 1 foot high, and a spouting pool between. All are in a large flat basin that connects with No. 6. The basin is about 30 feet in circumference.	186 to 200	This is a true geyser. For complete description see following notes.
8			Reddish and yellow spring in the center of a hard geyserite basin which was once evidently a geyser.
9	2 feet in diameter		A small pool with fissure holes near it.
10 11‡ 12§ 13¶	Bubblers		These springs are surrounded by holes and fissures. We were obliged to leave before completing their examination.
14. White Pyramid	Mound about 25 feet in height.		It steams slightly and may have periods of activity.
15. Punch Bowl	Basin with a crest 1½ foot in height.		This is probably a geyser.
16	5 by 6 feet		A small spring near the Punch Bowl.

* When quiet.
† At the surface; 11 feet below it is 169.
‡ Yellow-lined bulger with red border.
§ Bulging spring.
¶ Bubbler.

DESCRIPTION.

No. 2 is a bulging spring. When first seen it was a spring of two basins, but later the water rose and it was one basin with two orifices at the bottom, the right hand one being the bulger. The temperature here

FIG. 6.—Giant Geyser in action.

hen the water was low was 150° F.; when bulging it had increased to 86° F. The spring is on the edge of a platform of geyserite.

No. 4 is a flat basin with several holes (see table). It is on a platform of grayish-white geyserite.

No. 5. *Spray Geyser.*—This is probably a geyser, and should perhaps ave the name Comet which I have given to No. 7 provisionally. The tter I saw in action while I was close to it, but one afternoon an uption occurred in this group which I saw from a distance, and which emed greater than the eruptions I observed carefully in No. 7 on Sepmber 11. As the latter is known to be a geyser, I have for the present iven it the name Comet, and call this Spray Geyser.

The mound of No. 5 is 2½ feet high and beaded on the outside. The asin is 15 feet by 7 feet. It is yellow-lined, and the water had a temerature of 199° F. It was boiling violently during the time I saw it, nd I have no doubt that it is a geyser. If it should so prove to be, I ropose the name Spray Geyser for it, as indicated above.

No. 6. This is a handsome white basin in which the water is of a eautiful light-blue tint. In the outer portion of the basin where the ater is shallow the bottom is yellow, which becomes saffron and redolored as No. 7 is approached. The border, where the overflow from o. 7 comes into No. 6, is gray, and is raised about 3 inches. The outer m of No. 6 is continuous with the outer rim of No. 7, so that they are ally in one basin. The following temperatures were taken: At the rface after the eruption of No 7, 165° F.; 11 feet below the surface, 9° F. A large part of the overflow during the eruption of No. 7 assed away over No. 6.

No. 7. *Comet Geyser.*—This name is the one originally given to the rand by Colonel Barlow, and I have transferred it to this which, from l accounts, is a geyser of some importance. It has a large, flat, grayish, hite basin which connects with No. 6 when it is full. In about the nter of this basin are two mounds of yellowish-green-gray beaded yserite. The largest is on the west side, and is about 18 inches high ith a diameter of about 3 feet. The eastern one is only about a foot height, and has two orifices. These two mounds appear to be in conant action. Between them is a pool from which the spouting takes place. s south edge has masses of geyserite along it, like the two mounds, hough they are only 6 inches in height. Between the eruptions the ter in the pool is in ebullition. The following temperatures were en on September 11:

2.39 p. m.—Surface temperature, 191° F.
2.45 p. m.—Temperature 2 feet below the surface, 199° F.
2.51.50 p. m.—The eruption occurred.
2.55 p. m.—Surface temperature, 186° F.
2.56 p. m.—Temperature 3 feet below the surface, 200° F.

The following are the notes of eruptions taken September 11:

No. 1.—9.33.15 a. m.—The geyser spouts 25 or 30 feet at the maximum. An irregular splashing mass is thrown sideways and straight up to the air. The duration of the eruption was 1 minute 15 seconds.
No. 2.—1.37 p. m.—Spurts about 20 feet; duration 30 seconds.
No. 3.—1.50.45 p. m.—Spurts 15 feet; duration 1 minute 5 seconds.
No. 4.—2.10.10 p. m.—Eruption begins and lasts 55 seconds.
No. 5.—2.28.45 p. m.—Spouts to a height of 30 feet, with spurts in all ections. The eruption lasts 1 minute.
No. 6.—2.51.50 p. m.—An eruption begins, lasting 55 seconds.

The intervals and duration in tabular form are as follows:

Number.	Duration.	Interval.
	m. *s.*	*m.* *s.*
1	1 15	.....
2	0 30	.....
3	1 05	13 45
4	0 55	18 20
5	1 00	17 40
6	0 55	22 05

As far as these observations go they seem to point to a considerable uniformity in the action of this geyser. They may represent the frequent periods which so many geysers have.

At 3.15 p. m. on September 10 I saw from a distance an eruption of some geyser in this neighborhood. The column appeared to reach a height of at least 100 feet, so that I am rather uncertain about its being this geyser, although it may have been one of its regular eruptions. Dunraven, speaking of a geyser in this group, says:

In the largest basin are two apertures, and by one or both of these the water is constantly heaved up in a great rounded mass, like a huge bubble. The different basins are not in connection with each other. I was fortunate enough to see one of them in a state of great activity, but I was at some distance, and although I made all possible haste, the eruption, which only lasted a few minutes, had ceased before I arrived at the spot. The volume of water ejected appeared enormous, and I judged the height of the jet to be about 150 feet. I supposed this to be the Grand Geyser, but I see that Professor Hayden locates it at the other side of the river.*

The basin that Dunraven describes is without doubt the basin of No. 7, but whether the eruption is of that spring or of No. 5 I am uncertain, although I am of the opinion it is the latter, which I am also inclined to think is the one I saw in action from a distance.

This geyser (No. 7) is also the one mentioned by Professor Comstock when describing the Pyramid. He says:

Near its base are several fumeroles and *one fair-sized*, boiling or spouting, which possesses on a small scale all the essential characteristics of some of the simpler geysers.†

It seems, therefore, that No. 7, which I have named the Comet, is a rather constant spouter, but there is also in its vicinity a geyser that is first class in its action. Whether it is No. 5 remains to be determined by future investigation.

Springs 8–13 were mapped and descriptions partially taken when we were obliged to leave the basin. These temperatures were therefore not obtained.

No. 14. *White Pyramid.*—This conspicuous mound of white geyserite is back of the springs just described, and is a little over 500 yards from the river, about due west of the Giant. It is 200 yards from the main cluster of springs in the group, to which I have given its name, and most of the drainage from them passes it, going northward to flow into the Fire Hole below the cascades, where it again turns to the northwest. Judging from its size (it is 25 feet in height), it has once been a powerful geyser, but at present doubtless spouts very seldom if at all. A gurgling can be heard in it and steam escapes almost continually, but there is no evidence of recent activity. It has probably closed its vent by the gradual deposition of silica. It is pyramidal in form and stands out boldly against the dark evergreens that are back of it.

*The Great Divide, p. 274.

†Reconnaissance of Northwest Wyoming, by Capt. W. A. Jones, in 1873, p. 233.

No. 15. *Punch Bowl Geyser* (Plate XVIII). This handsome spring is 900 feet southwest of the Pyramid. It is remarkable for its crested rim, which rises 1½ feet above the general level. It is handsomely beaded and has a pointed border. A large area surrounding the spring is covered with siliceous deposit. Comstock found the spring active in 1873, and Captain Ludlow says it played frequently during August 23, 1875. (See p. 28, Report of reconnaissance from Carroll, Mont., to Yellowstone National Park and return in 1875.) We have never seen it in action.

CASTLE GROUP.

The springs included in this group are spread over an area of about 22 acres, and are dividable into several clusters, one of which is on the mound which has been built up about the crater of the geyser. Another (28–30) probably corresponds to the "Hidden Springs" of the map of 1872, as no other springs could be found in this neighborhood. They are 200 yards east of the Castle. North of them is another cluster (1–6) which is about 300 yards from the Castle. The remaining springs (7–18) are scattered along the edge of the river for a distance of over 300 yards northwest from the mound of the Castle. The Castle Group contains but one powerful geyser, viz, the one from which it is named.

Between the group and the river, extending southward towards the Three Crater Group and southeastward to within about 200 yards of Old Faithful, is an extensive marsh in which there is a small pond. The southeast side of this marsh is bounded by a terrace, which makes one of the best camping grounds in the Upper Basin. From it the principal geysers, except the Giant and Grotto, can be seen in action.

Table of the Castle Group.

Number and name.	Size and depth.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		°F.		°F.	
1. Four Bubblers...	*a* 3 by 3½ feet.....	*a* 183	.....	.....	*a b*, and *c* are continuously boiling and spurting; *d* is quiet.
	b 3 by 3 feet 3 inches.....	*b* 179			
	c 5 by 6½ feet.....	*c* 193			
	d 7 by 8 feet. Total length is 24 feet.	*d* 178			
2.....	53 feet long by 20 and 27 feet wide.	138	.....	.....	Red and green lined mossy basin.
3.....	7 feet diameter.....	130	.....	.....	Small red pool.
4.....	10 by 5 feet 4 inches, 2 feet deep.	136	.....	.....	Gray spring, with 4 openings.
5.....	17½ by 9 feet and 13½ feet....	151	.....	.....	Deep crater at one end.
6.....	4½ by 4½ feet	145	.....	.....	Gray pools.
7	7 by 11 feet, 3 feet deep	172	.....	.....	Muddy pool near river.
8.....	10 feet long	.....	.....	.....	Dead spring in grass near the river.
9.....	3½ by 5 feet, 2 feet deep	139	.....	.....	15 feet back of this is funnel 18 inches in diameter on mound.
10.....	Mound 18 inches 2 feet high, opening is 8 by 10 feet.	193	.....	.....	Spouter.
10*a*	.....	.....	.....	.....	Near 10 boils gently.
11.....	3 by 4 feet, 3 feet 9 inches deep.	145	.....	.....	Muddy pool.
12.....	1 foot by 18 inches.....	193	.....	.....	Water 8 inches below the top of the spring, which is red.
13.....	3 feet by 8 inches, or 1 foot..	170	.....	.....	Fissure in which there is clear water.
14.....	1 by 2 feet	197	.....	.....	Two sputtering holes, each 2 or 3 inches in basin.
15.....	Holes 1 to 3 feet long	135 137	}	.....	Hidden in grass.

Table of the Castle Group.

Number and name.	Size and depth.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		°F.		°F.	
16. Washtub	5½ by 5 or 6 feet	191	.....	.....	Crater of beaded silica, with others near it.
17. Dishpan	3 feet long by 8 inches, or foot wide.	198	.....	.....	Irregular fissure surrounded by sputtering holes.
17 *a*	6 by 7½ feet	185	.....	.....	Cone on river 6 feet above edge.
18		.....	.....	.....	Dead holes in the grass.
19	11 by 11 feet, 2 to 6 feet deep	191	.....	.....	Throws water 5 to 10 feet.
19*a*	Two small holes	{100 {101	}		
19*b*	3 feet by 18 inches	195	.....	.....	Close to river.
19*c*	5½ by 6 feet	109	.....	.....	Red pool.
20	8 by 10 feet	142	.....	.....	Yellowish-green pool.
21	The outside measures 19 feet 6 inches by 19 feet 9 inches.	188	.....	.....	This has always been one of the noted springs, and has frequently been photographed.
Beautiful Blue Crested Spring.	Spring basin, 14 by 15 feet inside. Depth, 44½ feet.	*195	.....	.....	
22	4 by 5 feet	184	.....	.....	} Beautiful springs.
23	3 feet wide	197½	.....	.....	
24	7 by 12 feet	186	.....	.....	A great boiler.
Castle, Jr	15 feet deep	†202	.....	.....	Near the Castle.
25	18 inches by 3 feet	171	.....	.....	Small hole.
26	6 by 10 feet	151	.....	.....	Red, leathery-lined pool, with two gently-boiling centers.
27	9 by 15 feet	189	.....	.....	Spring, with two basins.
28	13 by 14 feet	136	.....	.....	Greenish, red, and yellow deposit.
29	6 by 6 feet	166	.....	.....	Gray pool.
30	14 by 25 feet	140	.....	.....	Quiet pool.

*10 feet below the surface. †13 feet below the surface.

DESCRIPTION.

Castle Geyser (Plates XIX and XIX *a*).—This geyser has the most imposing crater in the Upper Basin, and was so named by Langford and Doane in 1870, because of its fancied resemblance to the ruins of a feudal castle, although from most points of view it is more like the ruin of a tower or turret on the end of a platform, suggesting the form of a "monitor iron-clad vessel." It is on the summit of a mound of white and gray deposit that covers about 3½ acres and rises about 40 feet above the level of the river. On this mound, 400 feet back from the river, is the platform on which the cone or turret is situated. This platform is composed of laminated geyserite, and is 100 feet in length by 75 feet in width, and on the north side is 3 feet above the level of the mound. On the south side the geyserite is much broken, and the destruction between the platform and the mound is not marked. The turret or cone is towards the west end of the platform, as viewed from the north, and rises 11 feet 11 inches above it, with a circumference at the base of 120 feet. The diameter on top is 20 feet. The contour is very irregular, especially on the east side, where there are a series of rough steps of globular masses of beaded silica (see Plate XIX). The deposit is very compact, and in many places has a silvery or leaden-gray color. The orifice of the geyser-tube on the summit of the cone is 3 feet in diameter, nearly circular, and lined with large beaded globular masses of a dull orange color. Steam is almost constantly escaping from this orifice, and jets of water occasionally spurt above it in the intervals between the eruptions.

1870.—Langford speaks of the Castle being in action at intervals of two or three hours and spouting to the height of 50 feet,* and Doane says he saw it on one occasion throwing water to the perpendicular height of 60 feet, with the escape of heavy volumes of steam.† They were of the opinion that the geyser was becoming extinct or at least had passed its most active stages of existence.

1871.—We saw no *bona fide* eruption of the Castle in 1871, but it was in frequent action, spurting irregularly to the height of 10 or 15 feet several times when we were in the neighborhood.

1872.—The eruptions we witnessed in 1872 began with a succession of jets numbering about 20 per minute, which reached various heights. These lasted about 15 minutes and were followed by a steam, mingled with spray, which escaped in pulsations which soon ceased and the steam escaped with a steady roar, which afterwards changed to an escape of cloud-like masses of steam. This gradually died down and ended an hour and twenty minutes after the beginning of the eruption. The following are the eruptions that were noted:

No.	Date.	Eruption began.	Duration of water period.	Duration of steam period.	Maximum height.	Mean height.
	1872.	*h. m. s.*	*m. s.*	*h. m. s.*	*Feet.*	*Feet.*
1	August 18	9 10 00 a. m.	.....	.....	Water 34	Water 21
2	August 19.....	10 30 00 a. m.	15 00	1 22 00 +	Water .....93 Steam 115	Water .....57 Steam 81
3	August 20	7 24 20 a. m.	16 00	.....	Water 51	.....

In the second eruption the maximum of the water period was attained 3 minutes 40 seconds after the eruption began. The steam was still escaping when we left the vicinity of the geyser, so that the period was not determined. The intervals are 25 hours 20 minutes and 20 hours 54 minutes 20 seconds; but we cannot be certain that the eruptions were consecutive as the night intervened in each case.

1873.—Professor Comstock witnessed parts of two eruptions. His description is as follows:

When we entered the basin early on the morning of August 25, the Castle was roaring vigorously, and a small amount of vapor escaped steadily from the vent at the summit. This gradually dwindled, and no eruption took place until the following day, although spurts of 2 or 3 feet only occurred at irregular intervals. Shortly before 4 p. m. on the following day, a large mass of water was ejected in a column which was maintained for two minutes at a height of nearly 30 feet. Leaving the basin one hour later, the roaring, which continued after the eruption, was still very audible at a considerable distance. From this it may, perhaps, be justly inferred that an eruption had taken place just before our arrival on the previous day. There was a certain fitfulness of action before and after the main ejection, all of which may properly be considered as part of one eruption, lasting more than one hour. We observed the phenomena from a little distance, when we were unable to devote any time to special examination. ‡

1874.—The Earl of Dunraven gives a graphic account of the eruption of the Castle, which I quote in full:

Far down in his bowels a fearful commotion was going on; we could hear a great noise—a rumbling as of thousands of tons of stones rolling round and round, piling up in heaps and rattling down again, mingled with the lashing of the water against the sides as it surged up the funnel and fell again in spray. Louder and louder grew the disturbance, till with a sudden qualm he would heave out a few tons of water and obtain momentary relief. After a few premonitory heaves had warned us to remove to a little distance, the symptoms became rapidly worse; the row and the racket increased in intensity; the monster's throes became more and more violent; the earth

* Scribner's Monthly for 1871, vol. ii, p. 124.
† Report of Yellowstone Expedition of 1870, p. 30.
‡ Report of Reconnaissance of N. W. Wyoming, by Capt. W. A. Jones, p. 250, 251.

trembled at his rage; and finally, with a mighty spasm, he hurled into the air a great column of water. I should say that this column reached, at its highest point of elevation, an altitude of 250 feet. The spray and steam were driven through it up to a much greater elevation, and then floated upward as a dense cloud to any distance. The operation was not continuous, but consisted of strong, distinct pulsations, occurring at a maximum rate of seventy per minute; having a general tendency to increase gradually in vigor and rapidity of utterance until the greatest development of strength was attained, and then sinking again by degrees. But the increase and subsidence were not uniform or regular; the jets arose, getting stronger and stronger at every pulsation for ten or twelve strokes, until the effort would culminate in three impulses of unusual power. The column of water appeared quite perpendicular, and was constantly ascending, for long before one jet had attained its greatest elevation, another had been forced through the aperture; but in the column the different efforts were plainly visible. The volume of water ejected must have been prodigious; the spray descended in heavy rain over a large area, and torrents of hot water, 6 or 8 inches deep poured down the sloping platform. The noise of the eruption was indescribable. I know of but one simile drawn from nature that conveys the smallest impression of it, and even then the impression is quite inadequate to illustrate the subject. Have you ever sat upon the very verge of a steep sea-cliff in a gale? I don't mean one of your yachtman's breezes, but a real *bona fide* full winter's gale of wind, roaring from the northwest over leagues and leagues of white Atlantic, and striking full against the cliff-face. If you have, you will know that there is at the edge a little space of complete calm, where the sea-pinks are scarcely stirred, and where you can sit and listen to the awful riot around you, untouched by it. If you will sit there, and are unaccustomed to such a scene, you will be half deafened and quite frightened by the strife of wind, and rock, and sea. Hear with what tremendous blows the gale strikes against the bold front of cliff and flies hoarsely howling with rage just over your head! Listen to its vicious scream as, baffled, it beats against the crags, and shrieks shrilly round some jutting rock! The ground seems to shake under the shock and thunder of the breakers against its base; and under all you will note the continuous hollow roar of the pebble bank crumbling to the sea with each receding wave. To all these sounds of elemental war add the shrieking of the steam-pipes of many steamers blowing off, and you will have some idea of an eruption of the Castle. Or, if you don't know much about the sea, you may imagine a gigantic pot boiling madly with a thunder storm in its stomach, and half full of great stones rolling and knocking about its reverberating sides. Taken with the above-mentioned steam-pipe accompaniment, which is indispensable, this may convey a faint idea of the noise. The total display lasted about an hour. Water was ejected for 20 minutes, and was then succeeded by steam, which was driven out with much violence and in great quantities. Like the water, it was expelled in regular beats, increasing in rapidity as the jet decreased in strength until the pulsations merged into one continuous hoarse roar, which gradually but fitfully subsided, and the exhausted geyser sank back into complete repose. To enjoy such a sight as this, a man should have time to get a little accustomed to it, for the display of such stupendous force exhibited in such an unusual manner is, to say the least of it, startling.*

This appears to be the only eruption witnessed, and must certainly have been a grander display than we have ever seen. The height is estimated, but it was certainly as high as any of the other geysers have reached. The Earl of Dunraven considers it the greatest geyser in the region, and his description certainly indicates this to be the fact.

1875.—Captain Ludlow speaks of the Castle giving off vast quantities of steam on the morning of August 22, and says it spouted 10 or 15 feet; "several times during the morning it repeated its performance, rarely exceeding, however, 20 or 25 feet."†

Grinnell and Dana, in the same report,‡ say that it was active during most of their stay, but that the amount of water discharged was never very great, and the highest jets did not exceed 50 feet.

1877.—The Castle was in constant agitation during Sherman's visit, but no well-defined eruption was seen.

1878.—The following are the notes of the eruptions I obtained in 1878:

August 28.—1.50 p. m. The eruption began, and reached a height of

* The Great Divide, pp. 265–268.

† Report of Reconnaissance from Carroll, M. T., to Yellowstone Park, &c., p. 27.

‡ Ibid., p. 132.

105 feet. 2.5 p. m. The water period is ended, and the steam escapes with steady thumpings. After some time there are periods of deep rumbling and thundering, after which the steam escapes with great violence. The steady roar can be heard in all parts of the Basin. 3.5 p. m. The steam is escaping very gently. 3.9.45 p. m. There is a slight roaring, lasting three-quarters of a minute, when the eruption is over.

August 29.—9.45.20 a. m. The Castle begins throwing water in irregular spurts; the height was not measured. 10.12.30 a. m. The steam begins to come out with a thumping noise. 10.21 a. m. The steam appears to be propelled in jets at intervals. 10.46.45 a. m. The eruption is at an end, and the steam is coming out as usual.

August 31.—8.45 a. m. There are several violent spurts from the crater, which lasted altogether 3 minutes 30 seconds. 8.49 a. m. Spurts began again, and in 30 seconds reached a height of 50 feet; then slowly sank, with steam intervals, until 8.50 a. m., when there was a violent spurt for a minute, followed by steam, after which there were occasional spurts at intervals of 10 to 60 seconds until 10.10 a. m., when the intervals became longer. These kept up during nearly the whole day, and probably represent the continuous action of the geyser in the intervals of the eruptions.

September 9.—During the night there was an eruption, but the time was not known. 12.39.25 p. m. An eruption began which reached a maximum height of 88 feet. 12.49 p. m. The steam eruption begins. The end of the steam period was not noted, as we were obliged to go to another portion of the Basin before it was ended.

The notes taken on the 31st of August were not those of an eruption, but of the constant action. None of the eruptions witnessed equaled the one noted by Dunraven in 1874. The escape of steam from the crater was so great that I did not succeed in obtaining any temperatures.

The following table composes all the eruptions that have been recorded. I include only those in which the steam period is noted as occurring after the water-spouting:

Date.	Observer.	No.	Duration of water period.	Total duration of eruption.	Maximum height of water eruption.
			m. s.	*h. m. s.*	
Aug. 18, 1872	A. C. Peale	1	.....	.....	34 feet, measured.
Aug. 18, 1872	....do	2	15 00	1 22 00+	93 feet, measured.
Aug. 18, 1872	....do	3	16 00	.....	51 feet, measured.
Aug. 25, 1873	Prof. Theo. B. Comstock	1	10 00	1 00 00+	30 feet, estimated.
Aug. 25, 1874	Earl Dunraven	1	20 00	1 00 00+	250 feet, estimated
Aug. 28, 1878	A. C. Peale	1	15 00	1 50 30	105 feet, measured.
Aug. 29, 1878	....do	2	27 10	1 1 25	
Sept. 9, 1878	....do	3	9 35	.....	88 feet, measured.

The observations are too isolated to determine the interval of the geyser. The points we have recorded prove that, besides the eruptive action, which has a well-defined course of procedure, there is a state of constant activity, which is accompanied by spurts, which reach 50 feet, or even 60 feet, as seen in 1870 by Doane and Langford. They, however, did not see a genuine eruption, in which the steam period is the most marked feature, and forms the peculiarity of the action of the Castle. There

appears to be a daily eruption of considerable magnitude, but the grandest eruptions seem to be separated by longer unknown intervals. It is probable that this is one of the oldest geysers in the Basin, if not in the world, and its future study promises to develop some important points. One thing is certain: its age does not interfere with the grandeur of the display when it has one of its characteristic eruptions.

Seguin speaks of witnessing an eruption of the Castle in 1879 which reached the height of 164 feet.*

Springs Nos. 1–6 are on a flat area of deposit, about 200 yards from the river, and are separated from it by a line of trees. They are of no special importance.

Nos. 7–18 are along the edge of the river, north of the mound of the Castle. They are but little above the river level. No. 10 is a spouter. No. 17*a* is a cone on the river's edge.

No. 16 is a pulsating spring. Besides the main basin, which is 5½ by 6 feet, there is a minor one with several holes. The craters are of pink-beaded silica. The main basin has two openings, from which the water rises gently at first, and is followed by bulges. It rises and falls at intervals of about 3 minutes.

Nos. 19–27 are on the mound of the Castle; 19 and 20 are near the river's edge, and are not specially important.

No. 21. *Beautiful Blue-crested Spring.*—This handsome spring is 150 feet north of the Castle, and has an almost circular basin, measuring 19 feet 9 inches by 19 feet 6 inches, bordered by a scalloped rim 6 inches in height, which projects slightly over the basin. The latter slopes to an opening on the southwest side, which measures 14 by 15 feet, and is somewhat funnel-shaped. The depth in this basin is 44½ feet. The water is of an ultramarine hue, which is intense over the deep portion of the basin. Whenever observed, the water was quiet and steaming very gently. There was little or no overflow, but the channel leading from the spring indicates that at times it must be considerable in amount. This channel is of gray, geyserite, lined with yellow and salmon-gray tints, which are deeper as the spring is left, deep yellows and reds replacing the grays. Words are inadequate to present a picture of the beauty of a spring of this description, for it is only one of the many that may be found in the Upper Basin. The following are the temperatures that have been taken:

	°F.
Surface temperature in 1871	172
Surface temperature in 1872	180
Surface temperature in 1878	188
Temperature 10 feet below the surface in 1878	195

These temperatures prove that there is a variation in the thermal condition of the spring, and point to the probability that at certain times there may be periods of active ebullition. It probably does not spout, as there is no indication of that fact in the surrounding deposits.

Springs 22, 23, and 24 are near the base of the Castle platform, on the northwest side. The first two have a common outlet, which is of a beautiful yellow and orange color, lined with bright red. No. 23 has a yellow and white rim, and is a double spouter. The temperature in it was 197½°. In 1872 it was recorded as 192°. Back of No. 22 the geyserite overhangs the spring.

No. 24. *Castle Junior.*—This is a very active boiling spring (shown in

*Mr. P. Norris, in his Report for 1881, p. 57, mentions two eruptions of the Castle. One occurred October 4, 1881, at 3 p. m., and reached a height of 75 feet, lasting 25 minutes; the other occurred at 9.45 a. m. on the 6th of October, reached a height of 100 feet, and lasted 30 minutes.

FIG. 7.—Grand Geyser, 1871.

the foreground of Plate XIX *a*), which occasionally spouts a few feet. It has a basin 7 by 12 feet, surrounded by beaded geyserite. Its surface temperature was 186°F., and at 13 feet below the surface, 202° F. It 1872 the surface temperature was 199° F., but it was taken near the time of action. During the water period eruption, No. 3 of the Castle, August 20, 1872, Castle Junior was pulsating, seeming to sink whenever there was a spurt of spray and steam from the Castle. During the steam period, however, Castle Junior was spouting to a height of 2 or 3 feet.

The remainder of the springs in this group are sufficiently described in the table.

GRAND GROUP.

The springs included in this group occupy an area of about 24 acres, extending 2,400 feet along the east side of the river opposite the Castle Group. The Grand Geyser is about the middle of the group, and is about 500 feet back from the river.

Besides the Grand, which is one of the prominent geysers of the Basin, there are several minor ones besides the Turban, which has attracted considerable attention on account of its handsome crater and its proximity to the Grand. The located springs are 56 in number, and are situated on a mound of geyserite that in most places slopes gently towards the river. At spring No. 39 (Limekiln), where the mound is steepest, the height above the river is 10 feet.

Besides the springs enumerated in the table, there are a number of steam vents and holes in the crust.

The springs are divisible into several clusters. Below the Grand Group, on the same side of the river are three springs that I have included with the Giant Group. They are separated from the lower springs of the Grand Group by a fringe of trees.

Table of the Grand Group.

[NOTE.—When not specified, the temperature is at the surface.]

Number and name.	Size and depth.	Temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1	4 by 4½ feet	150			In reality a long fissure expanded at points into pools or springs.
2	5½ feet wide	177			
3	*a*, 4½ feet long by 4 feet wide.	*a* 163			Fissure of about 15 feet, with two main basins.
		b 158			
4	21 feet diameter	169			Large greenish circular pool.
5	8 by 9 feet; 20 feet deep				Almost extinct greenish pool.
6	8 by 8 feet; 7 feet deep	162			White basin.
7	Basin 15 by 20 feet; spring 15 feet diameter.	168			
8	Basin 20 feet diameter; spring 10 feet diameter, 12 feet deep.	154			Greenish white spring, with white and red bordered basin; it has two outlets.
		*156			
9	18 inches diameter	173			Sputter hole at river constantly agitated.
10		163			A collection of holes, in which the water rises and falls regularly, flowing into the river. Spouts also a foot or two in splashes.
		†179			

* 11 feet below the surface.

† When spouting.

Table of the Grand Group—Continued.

Name and number.	Size and depth.	Temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
11	9 by 10 feet	170			Greenish white pool, with water rising and falling.
12	4 by 6 feet	186			Steaming spring on the edge of the river, where it boils under the bank with thud-like noise.
13	Cone 8 feet above the river and 2 feet above mound on the land side; top is 2 by 4 feet.	195			There are four holes on top and one at the base, next the river. They boil and sputter.
14	18 inches by 1 foot	178			Quiet spring.
15	1 foot by 2 feet	175			No. 14 and No. 15 are close to No. 13.
16	5½ by 8½ feet; 14 feet deep.	185 *196			Boiling spring, with rusty-yellow rim and greenish black-tinted water. Below 16 is a mound close to the edge of the river.
17	Cone 8 feet above river, 3½ by 4½ feet on top.	194	9.30 a. m	42	Geyserite cone; water escapes from it under a bridge of deposit.
18	Cone 15 feet above the river; 11 by 16 feet on outside; orifice 3 by 4 feet.	199			Irregular double-topped cone, almost level back of mound.
19	5 by 9 feet	195			There are two cones on edge, which are distinct. Water is in vigorous ebullition. Water outlet is lined with yellow and orange colors.
20	18 feet diameter	175			Circular pool; bubbles a little in the center.
21. Saw-Mill Geyser	Outer basin is 43 feet diameter; inner, 7 by 8 feet; funnel at bottom.	†176 ‡185			
22. Tardy Geyser	Basin 17½ by 18 feet; orifice 2 by 2 feet, with funnel at bottom 6 inches in diameter.	§163 ‖169	11 a. m		This is a geyser, from which steam comes in bulges.
23. Spasmodic Geyser	50 by 28 to 30 feet	193 *194	10.30 a. m	43	Double basin, with sputter-holes at one side; one basin has water constantly boiling. This is a small geyser.
24	2 feet diameter				Water is 2 feet below the surface.
25	9 feet by 2 to 4 feet	191			Double basin; one of them is lined with pearly deposit; the other spouts and sputters.
26	Cone				There are three openings near it.
27	26 by 30 feet	178			Basin without an outlet. The center is fissure-like.
28	11 feet by 6½ and 8 feet	178			White basin. Yellow outlet leads to a pool
29	13 by 20 feet	173			White pool, with two holes in it.
30. Bulger	Basin, 16 by 17 feet; inside it is 9 by 6 feet.	189			Water was 3 feet below surface. This is a geyser, throwing water 5 feet at times.
31	22 by 29½ feet; orifice about 2 by 3 feet.	124	12 m	47	Gray pool, in which water is quiet.
32	16 by 17 feet	126			Gray pool.
33	About 15 feet in diameter.	127			Gray pool, which sometimes overflows into No. 32.
Grand Geyser	Basin 52 feet diameter, 1 foot deep; orifice 2 by 4 feet.	189	12.5 p. m	47	(See following notes for full description.)
Turban Geyser	23 by 11 feet; 6 feet deep.	¶195			Do.

* 13 feet below the surface.
† In basin when quiet.
‡ When in action.
§ When basin is nearly empty.
‖ When full.
¶ During splashing.

CRATER OF THE GRAND GEYSER, UPPER FIRE HOLE BASIN

Table of the Grand Group—Continued.

Name and number.	Size and depth.	Temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
33½	*a*, 10 by 2 feet; typical of all the pools.	125			Collection of clear and muddy, cool pools in the grass.
34	23 by 39 feet; 15 feet deep.	184 *192			Large bluish pool near the river's edge; boils at one end.
35	12 feet by 6 and 7 feet	189			Boiling pool.
36	11 by 18 feet				Steam vent.
37	10 by 7½ feet; 6 feet deep.	160			Quiet pool.
38	Basin 23 by 32 feet; fissure 2 by 5 feet.	185			Crater, evidently an old geyser; boiling spring in fissure.
39. Limekiln Springs.	Cone is 8 to 10 feet above river level; *a* is basin, 5 feet wide by 7½ feet; *b* is cone, 2 by 3 feet.	*a*189 †194 ‡*b*			Both springs sputter and boil constantly.
40	9 by 11 feet				Lavender-colored mud pool.
41	60 by 15½ to 24½ feet; 15 feet deep.	182 189			Pool-like spring, with scalloped edge.
42	6½ by 6½ feet	178			
43	4½ by 6½ feet	159			Greenish-tinted water.
44	7 feet by 18 inches	*a* 176			Group of fissures and holes.
45	2 by 3 feet	193			Beaded geyserite hole; boils vigorously; near it is a fissure spring.
46	5½ by 6½ feet	§184			Geyser water rises and falls in yellow beaded basin spouts at intervals.
47	4½ by 6½ feet	148			White pool, shaped like bathtub. It is a quiet spring.
48	Basin 5 feet in diameter.	167			The water bubbles from a fissure in the basin.
49. Wave Spring	Outer basin is 18 by 28 feet; inner basin is 5 feet diameter; fissure at bottom is 18 by 6 inches.	182			Gray basin, in which the water is thrown into waves by the escaping steam.
50	Outer basin is 22 by 26½ feet; inner basin is 6 feet diameter.	169			Blue center in a gray basin, with scalloped rim; no outlet.
51	22 by 24 feet	167			Gray basin.
51*a*	6 by 5 feet				Back of No. 51.
52. Beauty Spring	14½ by 17 feet	168	2 p. m.	55	A very handsome spring, with greenish, white center and yellow edge, changing to red and saffron on outside.
53	18 by 9 feet; *a* is in center, 5 by 2 feet; *b*, in center, is 2 by 2 feet.	*a* 192 *b* 192			Two boiling springs in one basin.
54	49 by 51 feet	173			Blue pool, with cavern.
55	10 feet diameter	169			Blue spring, with gray edge.
56	22 by 31 feet	179			Large, bluish, green basin, with broad outlet.

* 14 feet below the surface.
‡ Not taken.
† 4 feet below the surface.
§ When quiet.

DESCRIPTION.

Grand Geyser (Plate XX).—Unless the eruptions of this magnificent fountain had been witnessed, one would scarcely take it for one of the most important geysers in the Basin; for, unlike Old Faithful, the Grotto, or the Giant, it has no raised cone or crater, nor even a huge cavern-like bowl, as in the case of the Giantess or Oblong. It is situated near the base of a hill, and is easily recognized by the crater of the Turban, which adjoins it on the north. The basin is 52 feet in diameter, and but slightly depressed below the surface, the greatest depth in the central portions being only about a foot. The bottom of the basin is very irregular, and near the mouth of the geyser tube is lined with

large cushion-like masses of geyserite, somewhat like those in the crater of the Turban. In these masses the orifice is 2 by 4 feet. It is situated near the Turban rather than in the center of the basin. There is no marked raised rim to the latter, but there are shallow basins and pools over the surrounding surface, the irregularity of which add to the beauty of the general effect. This geyser was called the Comet by Colonel Barlow, in 1871, but the same year we called it the Grand, which name has been retained. I have given the name Comet to a geyser in the White Pyramid Group. The descriptions following will give the best idea of the eruptions.

1871.—The Grand Geyser was first seen in eruption in 1871, having been unnoticed by the Washburn party in 1870. It spouted soon after our arrival, on the evening of August 4. We had just camped on the west side of the river, almost opposite the geyser, when a tremendous rumbling was heard, accompanied by a shaking of the ground and a huge escape of steam. It would be difficult to describe the feeling of excitement with which we saw the immense column of steam and water shoot from the crater to the height of 200 feet. The column was vertical and accompanied by immense clouds of steam, and the water in falling shook the ground. It was carried up in a succession of jets, the main mass being large, and the highest jets appearing to be forced through the latter. It was the first geyser of any power that we had seen, and we called it the Grand Geyser. The display lasted altogether about 20 minutes, and after it was over the water sank out of sight in the tube. The next day its temperature was 188° F., the water having again filled the basin.

The first eruption took place at 5 p. m., August 4. A second occurred at night on the 5th, after an interval of about thirty-one hours. A third one was noted by Colonel Barlow the last night of his stay, but the time was not noted.*

1872.—All the eruptions witnessed in 1872 occurred in the morning, two of them so early that we obtained only the time of beginning and time of ending. In order to get the height of the column, we kept guard one night near the crater. It did not spout, however, until daylight, when we succeeded in getting the height. The following are the eruptions noted:

First eruption, August 18.—Eruption began 5.20 a. m.; duration, 15 minutes.

Second eruption, August 19.—Eurption began 3.35 a. m.; duration, 37 minutes.

Third eruption, August 20.—Eruption began 6.33 a. m.; entire duration, 42 minutes.

This eruption was in three distinct periods, as follows:

Periods.	Spouting began.	Duration.	Interval of quiet.	Mean height.	Maximum height.
				Feet.	*Feet.*
First	6.33 a. m	3 minutes		79	122
Second	6.42 a. m	4 minutes	6 minutes	149	173
Third	6.56 a. m	9 minutes	10 minutes	53	84

This eruption did not appear to reach as great a height as the others. The interval between the beginnings of first and second eruptions was 22 hours. The intervals between the beginnings of second and third erup-

* Reconnaissance of the Yellowstone River, p. 25.

FIG. 8.—Grand Geyser in action, 1878.

tions was 26 hours. The third eruption began with 73 pulsations to the minute, which gradually died down to 71, and finally ceased entirely. In the third period the main eruption lasted only about 3 minutes, the other 7 being occupied by preliminary spurts, the maximum height being attained just 1 minute before the end. Just before it began the steam vent near by ceased acting. In the second period there were two quiet intervals, lasting a minute and a minute and a half. The maximum was attained on the first spurt, and the duration of each of the three spoutings was 30 seconds.

The maximum in the first period was reached in 30 seconds.

Preceding the eruption the water in the basin was lifted in a dome-shaped mass, and then the steam shot through it, carrying up the water in a mass that was somewhat pyramidal in shape. The highest jets were projected through this. The column was not much obscured by steam. After the action ceased, water ran into the basin from several channels, and in 3 minutes had sunk out of sight. Twenty-two minutes after the end, steam was still escaping from the orifice. About half an hour later the basin was filling, two large streams from the overflow of the Turban pouring in. In the Grand it was pulsating, falling from 1 foot to 6 or 8 feet, and rising again with occasional squirts. During this time the Turban was spurting, and the adjoining steam vent was in irregular action. I am of the opinion that the Grand, Turban, and steam vent are independent of each other. Professor Comstock, however, thinks there is sympathy to a certain extent. I shall refer to this again when speaking of the Turban Geyser.

1873.—Professor Comstock witnessed one eruption of the Grand in 1873, which he describes as follows:

Passing down the river a few rods, upon the right bank we saw a heavy mass of water rising in a square pool at the foot of a cliff some ten rods back from the stream. With a rush of wonderful power the column of dark blue liquid ascended nearly 200 feet, mingled with a cloud of dense white vapor, which rose to a much greater height. This tremendous fountain was kept suspended during five minutes, from 4.01 p. m., to 4.06 p. m. by a series of successive fierce impulses, which caused the surrounding platform of geyserite to tremble with the shock. The water then receded in the bowl, passing entirely out of sight, and remaining quiet during one-half minute; then playing vigorously for one minute in the same manner as at first; it again receded and remained quiet for one minute, afterward playing once more, even more fiercely than before, for two minutes, remaining quiet from 4.11 to 4.12, and then continuing with more or less of vigor until $4^h\ 12^m\ 5^s$ p. m. At $4^h\ 17^m\ 5^s$ p.m. vapor issued from the mouth of the bowl, and water was ejected at $4^h\ 20^m\ 5^s$, continuing until 4.24, when the action ceased, the water, as in every case, receding to a great depth. Spurting took place at $4^h\ 28^m\ 5^s$, gradually increasing in intensity, with occasional jets, until 4.31, when it again spouted 200 feet till $4^h\ 32^m\ 5^s$ p. m. Remaining quiet until $4^h\ 48^m\ 5^s$, it again spurted several times, less rapidly than before, but very gradually increasing in power and frequency, till 5.47 p. m., when the action wholly ceased.*

In this eruption there would appear to be four periods instead of three, as in the eruptions noted in previous years. Tabulating them, we have the following:

No. of period.	Spouting begins.	Duration.	Intervals of quiet.	Maximum height.
	h. m. s.	*m. s.*	*m. s.*	*Feet.*
First	4 01 0 p. m.	11 15	.....	.....
Second	4 20 5 p. m.	3 55	7 50	.....
Third	4 28 5 p. m.	4 00	4 5	200
Fourth	4 48 5 p. m.	58 55*	16 0	.....

*I think the time of ending, 5.47, should be 4.57, which which would give a duration of $8^m\ 55^s$, instead of $58^m\ 55^s$.

*Report of Reconnaissance of N. W. Wyoming in 1873, p. 252.

The total duration, if the time of ending is 5.47 p. m., as published, is hour and 46 minutes. I think, however, that this should be 4.57 p. m., a Professor Comstock speaks of its spurting *several* times, and graduall increasing in power during the last period (58 minutes). If it is 4.5 the total duration would be 56 minutes, which is a little longer tha has been previously observed. There are, however, four periods, whic may account for the greater length. As observed in 1872, the longe period is the last.

1874.—Dunraven did not witness an eruption of the Grand.

1875.—Dana and Grinnell describe an eruption witnessed by them a follows:

> The height of the first discharge did not much exceed 100 feet. It rose to this poi in a series of violent pulsations, remained at this altitude for 3 or 4 minutes, and the sank back into the pool, which became quite still. A moment later it had commenc again, the water rising certainly 150 feet by estimate. This again sank down, an again rose to its maximum height, and this was twice repeated.*

Captain Ludlow, speaking of this eruption, says:

> Meanwhile the neighboring geyser [Turban] was splashing its waters in all dire tions and discharging clouds of steam, while a steam vent close at hand kept up a mo outrageous roar. †

Only one eruption appears to have been witnessed by the party, s that nothing was noted in regard to the interval of the geyser.

The maximum was attained in the third period, as in the case of th eruption observed by Professor Comstock in 1873.

The data are not sufficient to give the lengths of the periods for com parison with the other eruptions already noted.‡

1878.—Six eruptions were noted during the season, four occurrin during our first visit and two during the second They were noted fro a distance, the heights being taken from a base line of 2,500 feet. Th following are the eruptions:

First eruption, August 27.—Eruption began 3.55 p. m.; duration, 1 minutes 45 seconds.

Second eruption, August 28.—Eruption began 11.26 a. m.; duration, 1 minutes.

Third eruption, August 29.—Eruption began 4.14 p. m.; duration, 1 minutes 45 seconds.

Fourth eruption, August 30.—Eruption began 9.09 a. m.; duration, 1 minutes 30 seconds.

Fifth eruption, September 9.—Eruption began 10.15 p. m.; duratio not taken.

Sixth eruption, September 10.—Eruption began 8.15.30 p. m.; duratio 15 minutes 20 seconds.

The following are the intervals between the beginnings of eruptions

Between first and second eruptions, 19 hours 32 minutes.

Between second and third eruptions, 28 hours 48 minutes.

Between third and fourth eruptions, 16 hours 55 minutes.

Between fifth and sixth eruptions, 22 hours 00 minutes 30 seconds.

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* Reconnaissance from Carroll, M. T., to Yellowstone National Park, &c., p. 131.

† *Ibid*, p. 27.

‡ In 1881 Colonel Gregory, with General Sheridan's expedition, saw an eruption the Grand with 8 distinct spoutings, the total time of the eruption being 22 minute (*See page* 21 *of General Sheridan's report.*)

The following table shows the periods as nearly as they can be determined:

Eruption.	Periods.	Duration.	Intervals.	Maximum height.	Remarks.
	No.	*m. s.*	*m. s.*	*Feet.*	
irst	1	7 00			
	2	1 45	0 45		
	3	1 30	4 45		
econd	1	9 00			
	2	1 30	1 00		In the second period there were two spurts.
	3	2 30	2 00	165	In the third period there were three spurts with the following intervals, 1m. 45s. and 0m. 45s.
hird	1	8 30			
	2	3 23	0 22		In the second period there were three spurts with intervals of 1m. 33s. and 1m. 45s.
	3	5 00	1 30		They lasted only a few seconds, the last one 5s.; one spurt in third period 5s. long.
ourth	1	8 30		95	
	2	(*)	3 00		One spurt in second period.
ifth	5 or 6	(†)			I could not determine spurts from periods.
xth	1	9 00			
	2	3 25	00 15		Three spurts in second period, with intervals of 1m. 35s., 1m. 10s. and 0m. 40s.
	3	0 20	2 20		Two spurts in last period, interval of 0m. 20s.

*One spurt not timed. †Not taken.

The fourth eruption was noted by Mr. Ladd, and the measured height was not of the highest eruption which was attained in the last spurt, and was so much obscured that he could not take the angle. The instrument was not set up when the first and third eruptions were noted, and when the fifth and sixth occurred it was too dark to read the angles.

A comparison of the tables that I have given seems to indicate that the Grand is very irregular in its action; but we must remember that the observations are not consecutive over a long time, and until they are carried through at least a period of several months consecutively we cannot predicate anything as to the laws of action it has. What now appear to be irregularities may recur at regular periods. We know very little also as to the effects of the varying supplies of water that may occur at different seasons. It is to be hoped that at some time a party will be stationed on the Upper Basin to carry on observations extending through several consecutive seasons. An eruption of 10 minutes' length was noted from a distance at 6.40 p. m. on the evening of August 26. It is not included in the table, as we could not be absolutely certain of its being the Grand.*

*The following observations on the Grand Geyser is taken from Mr. P. W. Norris' Report for 1881, p. 56:

Date.	Time of eruption.	Duration of eruption in minutes.	Height of the column of water in feet.	Remarks.
1881.				
Oct. 4	9.45 a. m	20	200	Observed by Rowland. The column of water at all of these eruptions was vertical and of remarkable symmetry and beauty.
4	5.10 p. m	25	200	
5	3.25 p. m	20	200	
6	9.15 a. m	20	200	
6	4.20 p. m	20	200	

On the 10th of September, at 12 o'clock, the temperature in the basin of the Grand was 189° F. The basin was full and receiving some of the overflow of the Turban. This temperature is practically the same as that taken in 1872 (188° F.). No temperatures were taken immediately prior to the eruption, but there is no doubt that it is higher then than at other times.

Turban Geyser (Plate XXI).—Although one of the minor geysers of the Upper Basin, it has attracted considerable notice from its connection with the Grand, and from its peculiar crater, which is well shown in the illustration. It was named in 1872 from the fancied resemblance of some of the large globular masses in its basin to a Turkish headdress. These masses are irregular in form and size, and are found around the rim as well as in the bottom of the basin. They are yellow, and some look like squashes or pumpkins.

The Turban and Grand are on the same platform of deposit, the former being raised about 3 feet above the latter. The basin of the Turban is irregularly quadrangular in form, 23 feet in length and 11 feet wide. The depth is 6 feet. The geyser orifice is at the north end, and is very irregular in shape, measuring 3 by 4 feet. Preceding the eruption the water rises and fills the basin, and after the action ceases it sinks in the tube very rapidly, leaving the basin entirely empty, as shown in the illustration. During the eruption it is violently agitated, and the mass is so large that the height attained is not great, the water being splashed out irregularly in all directions. Surrounding the Turban are shallow pools with ornamented rims.

No observations were made in 1871 other than to note the form of the basin.

1872.—The following are the notes taken in 1872:

August 20.—6.58 a. m., spurts for three minutes, attaining a height of 25 feet. 7.5.30 a. m., spurts again, lasting 15 seconds, height only 10 feet. Two and a quarter minutes later the basin is empty. Thirty-four minutes after, steam escapes and the water rises. 7.32.30 a. m., small spurts. 7.37 a. m., spurts, the maximum height being 22 feet. 7.44 a. m., the basin is full and water overflowing into the Grand.

In this eruption, or rather in the two eruptions, which are separated by a period of 26 minutes and 45 seconds, we cannot determine much as regards the interval. The first began 2 minutes after the second period of the Grand began, *i. e.*, 25 minutes after the beginning of the first period, and lasted 45 seconds longer than the end of the eruption of the Grand. The second began 27½ minutes after the Grand had finished its eruption. This would appear to indicate independence in action.

The steam vent spurted steam and water at 7.38 a. m., *i. e.*, while the Turban was in action, and after the Grand had subsided. It was in action before the latter, and while the two were in action simultaneously it was quiet. The Turban was not observed during the first and second eruptions of the Grand, as they occurred early in the morning, and we were in camp across the river.

1873.—Professor Comstock saw the Turban in action during the eruption of the Grand. His description agrees closely with the eruption noted by myself in 1872. He says:

> Shortly before an eruption, as is common in the geyser basins, the water rises so as to fill the pit. At 4.09 p. m., August 25, during one of the spoutings of the Grand Geyser, the water in the Turban was agitated, boiling up in a powerful throb to a height of 3 feet, with occasional protracted spurts varying from 20 to 30 feet. At 4.12.5 the water receded far down the subterraneous passage; at 4.17 p. m. vapor ascended, followed by water at 4.17.5, after which the agitation was variable in degree, being continued without interruption until 5.40. Frequently during the eruption quantities of

CRATER OF THE TURBAN GEYSER. UPPER FIRE HOLE BASIN

water poured over the rim of the bowl, a considerable portion flowing directly into the mouth of the Grand Geyser, and apparently producing an important effect upon the action of the latter.*

In this there are really two eruptions, separated by an interval of 5 minutes, instead of over 26, as in the eruption I observed. It began 8 minutes after the Grand began to act. The second eruption was preceded by an escape of steam, which corresponds with what I observed. In the 1 hour and 23 minutes which he gives as the duration of the second eruption I am of the opinion there were a number of eruptions, judging from what I saw in 1878, and from the fact that Professor Comstock says the agitation was variable.

1875.—Captain Ludlow, in describing the eruption of the Grand witnessed by him, says that the Turban and Steam Vent both were in action with the Grand.

1878.—The eruptions of the Grand having been noted from a distance, the behavior of the Turban during its action could not be noted.

The Turban was seen spouting at 3.59 p. m. on August 26, and at 9.15 a. m. and 6.48 p. m. on the 30th, and at 11.02 a. m. on the 31st by Mr. Richardson, but beyond the fact that it was spouting nothing was noted. On our second visit to the Basin, while mapping and investigating the springs of the Grand Group, I obtained the following notes on the Turban. The temperature a little after 12 o'clock, while the splashing was going on, was 195° F. The following notes of the eruptions were obtained:

September 10.—11.40 a. m., splashes and spurts to 5 or 6 feet. 11.45 a. m., action ceases. 12.10 p. m., spurting begins again, 5 or 6 feet. 2 p. m., the geyser is perfectly quiet. 2.15.15 p. m., the water begins to bulge and overflows to Grand. 2.18 p. m., bubbling quietly. 2.19 a. m., action ceases. 2.34.50 p. m., bulges again. 2.38.30 p. m., action ceases. 2.54 p. m., spouting. 2.57.30 p. m., action ceases. 3.12 p. m., spouting. 3.14.50 p. m., action ceases.

The eruption of the Grand on September 10 did not occur until 10.15 p. m. During the spoutings of the Turban just noted the basin of the Grand was full, and the water in it was perfectly quiet. Whether the splashings I have noted were periods of one eruption or distinct eruptions I cannot say. The time devoted to the examination of this geyser was too short to determine much.

In the following table, for the sake of comparison, I bring together all the eruptions of the Turban that I have recorded in the previous pages, considering each period of spouting as an eruption.

Date.	No.	Duration.	Intervals.	Observer.
		h. m. s.	*m. s.*	
August 20, 1872	1	0 3 00	.....	A. C. Peale.
	2	0 0 15	4 30	Do.
	3	.....	26 45	Do.
	4	0 3 00	.....	Do.
August 25, 1873	1	0 3 05	.....	Prof. Theo. B. Comstock.
	2	* 1 25 00*	5 00	Do.
September 10, 1878	1	0 5 00	15 10	A. C. Peale.
	2	0 3 10	(†)	Do.
	3	0 4 15	.....	Do.
	4	3 40	15 50	Do.
	5	4 30	15 30	Do.
	6	2 50	14 30	Do.

* As I have indicated in another place, this probably includes several eruptions.
† Nos. 2 and 3 of 1878 are not consecutive.

* Reconnaissance of Northwestern Wyoming in 1873, &c., p. 253.

These facts are recorded in the hope that ultimately, when more dat are accumulated, they may help to solve some of the problems presente by the geysers.

I think that the balance of proof is against the idea that there is an connection between the Turban, the Grand, and the Steam Vent (inco rectly called the Saw-Mill by Comstock). The Turban acts frequentl and it is merely a coincidence when it acts in concert with the Grand Professor Bradley in 1872 thought that the Turban was startled int more violent action by the eruption of the Grand, and saw it rise an fall synchronously with it. The same year, however, as I have noted it was quiet during some of the most active periods of the Grand an spouting during others. As to the Steam Vent, I saw it in action ju before the eruption of the Grand, during which it was perfectly quie whereas Professor Comstock saw it spouting simultaneously and cea ing with the Turban and Grand.

No. 21. *Saw-Mill Geyser.*—This name was given in 1871 by Mr. Scho born, our topographer, to a very active little geyser on the same mour or terrace with the Grand, from which it is distant 450 feet to the sout ward, being separated only by a few trees. It is a very interesting ge ser, although one of the smallest in the Basin. The mass of water throw up is not great in quantity, but it is so broken into spray and glitterin crystal drops that it presents a beautiful appearance, especially in th bright sunlight, when a rainbow may be seen in its fountain-like colum Preceding the eruption the basin fills with water. The following is th description of the eruption I witnessed in 1872:

There were noticed during the eruption five distinct periods of actio per minute, each one made up of fifteen impulses. While this is goin on the mass of water pulsates and reaches a height of about 5 feet, an through this jets shoot to 15 or 20 feet. The following are the not made in 1878:

August 27.—Saw-Mill is in action at 6.25.15 p. m.

August 28.—Saw-Mill is spouting at 12.21.41 p. m. 3.19 p. m., spou for 3 hours.

August 29.—8.32.52 a. m., spouts for about 3 hours. 4.36 p. m., spout but duration not ascertained.

August 30.—1.20 p. m., in action. 5.20 p. m., in action.

August 31.—10.15 a. m., in action.

September 8.—7 p. m., Saw-Mill is spouting.

September 9.—11 a. m., in action. 6.38 p. m., began to spout.

September 10.—9.50 a. m., the inner basin is filled with water. 10.3 a. m., outer basin is filling. 11.46 a. m., the spouting begins wi thumpings and lively spurts, 20 to 25 feet. The duration of the eru tion is 1 hour and 49 minutes. After the eruption steam escapes, an in half an hour the basin is empty. 2.45 p. m., the basin is fillin 3.17.45 p. m., the Saw-Mill begins action with a whirling motion to th mass of water and occasional high spurts. The eruption lasts 2 hour 12 minutes and 15 seconds.

The interval between these eruptions was 3 hours 31 minutes an 45 seconds; the interval of quiet being 1 hour 47 minutes and 45 se onds. There are probably about five or six eruptions in 24 hour although more observations are necessary to determine positively th exact interval. The Saw-Mill Geyser described by Professor Comstoc in his report (p. 254) is not the one we named in 1871, but the stea vent near the Grand. I have taken the name he gives its companio for the companion of the Saw-Mill, viz, No. 22, and called it Tar Geyser.

The basin of the Saw-Mill is shallow, measuring in its outer dimensions 3 feet in diameter. Inside of this is a second basin 27½ feet in diameter, overed with pebbles. The outer circle is bordered by spongiform masses. n the center the geyser tube is funnel-shaped, 7 feet in diameter, sloping o a small orifice. In the outer basin or circle there is a small hole or eam vent. In the outer basin the temperature during the quiescence the geyser was 176° F. During the second eruption, noted on Septem-er 10, the temperature was 185° F. This was, however, not in the nter, as the spurts prevented the obtaining of it at that place.

No. 22. *Tardy Geyser.*—This geyser has a circular basin about 18 feet diameter, much like the Saw-Mill, which is only a few feet north of it. n the center is a funnel-shaped orifice 2 by 2 feet, sloping to a hole 6 ches in diameter. The temperature while the water was quiet and filled ly the basin of the funnel was 163° F. At 11 a. m., September 10, e basin was full and the steam escaped in bulges about every 2 min-es, and the water had a temperature of 169° F. It spouted during the st eruption of the Saw-Mill, the action being very similar, but not aching quite so high an altitude. During the second eruption of e Saw-Mill the Tardy was quiet. Nothing was determined as to its eriods or length of action.

No. 23. *Spasmodic Geyser.*—This name I have given to a basin with vo orifices, that spouts at intervals not determined. When examined, 10.30 a. m., September 10, the water was low and had a surface tempera-re of 193°, and a deep temperature (13 feet below the surface) of 194°, nd was in active ebullition. At 2 p. m. the water was 3 feet below top of e basin, and at 3 p. m. it filled it and was spouting vigorously to a eight of 3 to 5 feet. The outer basin is 50 feet in length by about 30 et in width over the two inner basins or orifices, which are much smaller nd almost circular.

Nos. 24 and 25.—These are small spouters. In the morning of Sep-mber 10 the water was low and was pulsating; at 2 p. m. they were npty, and at 3 p. m. were full and spouting actively, the jets reaching eights a couple of feet above the craters.

No. 30. *Bulger Geyser.*—This is a cone surrounded by beaded geyserite nd having an oblong basin, in which the water rises and falls period-ally. At 10.30 a. m. the water was 3 feet below the top and had a tem-erature of 189° F. At 11.52.45′ a. m. the steam was escaping and rowing the water in a bulging mass to the height of 5 feet. The rings included in the group are sufficiently described in the table, and shall not, therefore, repeat the descriptions here.

Springs Nos. 1–5 form a small cluster, the drainage from which goes o the Fire Hole at the bend just below the limits of the Giantess roup.

Many of the springs of the group are situated along the edge of the ver, and opposite them, at a lower level, are a number of springs that re included with the Castle Group. Springs 31–33 are surrounded with deposit of gray geyserite.

The Limekiln Springs are so called from the fancied resemblance of ne mound on which they are located to a deserted limekiln.

OLD FAITHFUL GROUP.

The first thing likely to attract the attention of the visitor to the Up-er Geyser Basin, especially if he comes from the south, is the Old Faith-ul Geyser. It is near the south end of the valley, on the left side of the ver, 700 feet from the river edge, and is surrounded by four cones,

which probably mark the sites of extinct geysers, their deposits being broken and shelly, evidently disintegrating. From one of them steam escapes occasionally, but the orifice is so choked with broken geyserite that I was unable to take the temperature of the water in it. This cone is one of the favorite points from which to view the eruptions of Old Faithful. There are several small vents on the mound of the geyser, which appear to mark the line of a fissure of the orifice of which the geyser is a part. It is probable that Old Faithful is the most recent of the cones, or mounds, which mark this location, and that when it broke forth the other cones ceased their geyseric action. The springs of the group are near the river, on a high mound, which, however, is lower than the level of the geyser. They have high temperatures. The following table presents all the data in reference to them:

Table of Old Faithful Group.

No. and name.	Size and depth.	Surface temperatures.	Deep temperatures.	Time of observation.	Temperature of air.	Remarks.
Old Faithful geyser.	Orifice is 2 by 6 feet.	*199 †200 ‡170	.....	5.30 p. m. 5.50 to 5.58.	....	For further notes on temperature, see text following table.
1.....	Cone.....	.....	.....	.....	....	Choked with deposit.
2.....	6½ by 9 feet; 7 feet 10 inches deep.	197	6½ feet below the surface, 200°.	.....	....	Greenish-hued pool.
3.....	4 by 5½ feet; 15½ feet deep.	196	14 feet below the surface, 199°.	.....	....	Boiling spring, with inky-hued water in a white basin, with white border.
4.....	3 by 3 feet 3 inches; 16 feet deep.	198	14 feet below the surface, 207°.	.....	....	Black boiling spring.
5.....	9 by 16 inches.....	185	.....	.....	....	Small hole near the geyser.

* Steam 4 or 5 feet in crater. † Spurts of steam. ‡ Pools outside.

DESCRIPTION.

Old Faithful Geyser (Plate XXII).—This geyser was named by Mr. N. P. Langford, and well sustains the reputation given it by the Doane and Washburn expedition of 1870. It has been called the Guardian of the Valley. It is so regular in its operations and they occur so frequently that it has afforded unusual facilities for observation. It is a mound or table of geyserite, measuring at the base 145 by 215 feet, and at the top 20 by 54 feet. It rises 11 feet 11 inches above the surrounding level, and is composed of layers of deposit arranged in a succession of small steps that are made up of small basins. Near the top these basins are beautiful, broad, shallow pools, with pink, cream, white, brown, and gray bottoms, in which the water after the eruptions stands and is of a deep-azure tint.

The chimney, or crater, of the geyser has an oblong opening measuring 4 by 8 feet on the outside and 2 by 6 feet inside. This slopes inward, and is the top of a basin about 5 feet deep, at the bottom of which is an irregular orifice, the head of the geyser tube. The inside of the basin is of a dark-yellow and rusty color. There is little doubt that this orifice marks the situation of a former fissure, and this part has been formed into a basin by the deposition of geyserite on its sides, which has acted as a perfect cement. This fissure was probably in geyserite, at the surface at least, and was caused perhaps by some obstruction in some of the

OLD FAITHFUL GEYSER IN ACTION
UPPER FIRE HOLE BASIN.

geyser cones that are seen near Old Faithful, which rendered a new outlet necessary. The continuation of the fissure may be traced, although it is almost entirely closed. The north end of the crater has large globular masses of beaded, pearly deposit. The throat of the geyser and the edges of the basins also are beaded. Lieutenant Doane thus describes the deposits around Old Faithful:

Close around the opening are built up walls, 8 feet in height, of spherical nodules from 6 inches to 3 feet in diameter. These, in turn, are covered on the surface with minute globules of calcareous [siliceous] stalagmite (?), incrusted with a thin glazing of silica. The rock at a distance appears the color of ashes of roses, but near at hand shows a metallic gray, with pink and yellow margins of the utmost delicacy. Being constantly wet, the colors are brilliant beyond description. Sloping gently from this rim of the crater, in every direction, the rocks are full of cavities, in successive terraces, forming little pools, with margins of silica the color of silver, the cavities being of irregular shape, constantly full of hot water, and precipitating delicate coral-like beads of a bright saffron. These cavities are also fringed with rock around the edges, in meshes as delicate as the finest lace. Diminutive yellow columns rise from their depths, capped with small tablets of rock and resembling flowers growing in the water. Some of them are filled with oval pebbles of a brilliant white color, and others with a yellowish frost work which builds up gradually in solid stalagmites (?). Receding still farther from the crater, the cavities become gradually larger and the water cooler, causing changes in the brilliant colorings, and also in the formations of the deposits. * * * The deposits are apparently as delicate as the down on the butterfly's wing, both in texture and coloring, yet are firm and solid beneath the tread. * * * One instinctively touches the hot ledges with his hands, and sounds with a stick the depths of the cavities in the slope, in utter doubt in the evidence in his own eyes.*

The eruption of Old Faithful begins with some preliminary splashes or spurts, from three to a dozen or more, which appear like abortive attempts at eruption. These continue for about 4 minutes, becoming more and more powerful, when they are followed by a rapid succession of jets, which escape with a roar and soon attain the maximum height. Clouds of steam accompany the water and reach a much greater height. In a few seconds after the maximum is attained the column dies down, with occasional vigorous spurts. The water eruption is followed by steam, which soon comes out very gently, and finally dies away, leaving the crater empty. The water eruption lasts from 4 to 5 minutes, and the steam period is indefinite. The wind causes a great variation in the appearance of the column, but the accompanying plate (Plate XXII) shows perhaps the most frequent form. This year I noticed that before the eruption, although the basin was empty, spurts were thrown from below into the basin, but did not go above the top. These observations will be detailed with the account of the temperature. I will present my observations under the head of 1878, after first giving the observations of preceding years in regular order, beginning with 1870.

1870.—From the descriptions given by Mr. Langford in Scribner's Monthly, Vol. II, and Lieutenant Doane, it is evident that the character of the eruptions in 1870 were the same as noticed in subsequent years. Lieutenant Doane says:

The period of this geyser is 50 minutes.† First an increased rush of steam comes forth, followed instantly by a rising jet of water, which attains by increased impulsions to the height of 125 feet, escaping with a wild, hissing sound, while great volumes of steam rise up to an altitude of 500 feet from the crater. Rainbows play around the tremendous fountain; the waters, which fall about the basin in showers of brilliants, then rush steaming down the slopes to the river. After a continuous action for a space of 5 minutes, the jet lowers convulsively by degrees, the waters finally disappear, and only a current of steam pours forth from the crater.‡

* Yellowstone Expedition, &c., pp. 28, 29.

† In Washburn's account (Raymond's Mining Statistics, 1870, p. 216,) the time is given as every hour and the height 75 feet.

‡ Yellowstone Expedition, p. 29.

1871.—As we entered the Upper Geyser Basin in 1871 late on the 4th of August and left early in the morning of the 6th, we had but little opportunity for observations, as a great part of the time was spent in other portions of the Basin. Captain Barlow, who was there at the same time, records a measurement of Old Faithful's column as 138 feet.* We estimated the height as from 125 to 150 feet. No accurate time observations were made.

1872.—I spent three days in the Upper Geyser Basin in 1872, and most of one of these days I spent in the neighborhood of Old Faithful, in order to record the eruptions which are given below in tabular form, which is the same as that given in the report of 1872,† save that an additional column is given and the others are rearranged, while corrections are added. I found it impossible to obtain the temperature of the water, as I had no self-registering thermometers, and the escape of steam was so great that I could not use an ordinary instrument. I attempted to obtain the depth of the geyser, but the rope became tangled and I found it impossible, largely on account of the irregularities in the geyser tube. The heights given in the following table were from the end of a base line 100 feet long:

Table of observations of 1872.

Number of eruption.	Date.	Eruption began.	Eruption ended.	Time of maximum height.	Intervals between beginnings of eruptions.	Intervals of quiet.	Duration of eruptions.	Interval between beginning and maximum.	Average height.	Maximum height.
	1872.	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*s.*	*Feet.*	*Feet.*
1	Aug. 17	3 22 00 p. m.	3 27 00 p. m.	.....	.....	.....	5 00	.....	.....	.....
2	Aug. 18	7 27 30 a. m.	7 32 30 a. m.	.....	.....	.....	5 00	.....	.....	.....
3	Aug. 18	8 35 30 a. m.	8 40 30 a. m.	.....	1 08 00	1 03 00	5 00	.....	.....	.....
4	Aug. 18	9 40 30 a. m.	9 46 30 a. m.	.....	1 05 00	1 00 00	6 00	.....	.....	.....
5	Aug. 18	10 46 26 a. m.	10 51 13 a. m.	10 46 27 a. m.	1 05 56	59 56	4 47	1	49.4	106.3
6	Aug. 18	11 54 31 a. m.	11 59 10 a. m.	11 55 00 a. m.	1 08 05	1 03 18	4 39	29	45.0	130.3
7	Aug. 18	1 05 05 p. m.	1 09 46 p. m.	1 05 20 p m.	1 10 34	1 05 55	4 41	15	52.2	125.5
8	Aug. 18	2 15 25 p. m.	2 20 15 p. m.	2 15 46 p. m.	1 10 20	1 05 39	4 50	21	49.9	125.5
9	Aug. 18	3 23 51 p. m.	3 28 22 p. m.	3 24 10 p. m.	1 08 26	1 03 36	4 31	19	31.9	120.8
10	Aug. 18	4 33 22 p. m.	4 38 22 p. m.	.....	1 09 31	1 05 00	5 00	.....	.....	.....
11	Aug. 18	5 41 00 p. m.	5 46 00 p. m.	.....	1 07 38	1 02 38	5 00	.....	.....	.....
12	Aug. 18	6 42 30 p. m.	.....	.....	.....	.....	.....	.....	.....	.....
13	Aug. 18	7 44 30 p. m.	.....	.....	.....	.....	.....	.....	.....	.....
14	Aug. 18	8 51 00 p. m.	.....	.....	.....	.....	.....	.....	.....	.....
15	Aug. 19	10 07 00 a. m.	10 11 45 a. m.	.....	.....	.....	4 45	.....	.....	.....
16	Aug. 19	11 12 30 a. m.	11 17 20 a. m.	.....	1 05 30	1 00 45	4 50	.....	.....	.....
17	Aug. 20	11 54 00 a. m.	11 58 20 a. m.	.....	.....	.....	4 20	.....	.....	.....
Average intervals					1 07 54	1 02 58	.....	17	.....	.....
Average duration					.....	.....	4 53	.....	.....	.....

1873.—Professor Comstock's description of the eruption in 1873 is like that of preceding years. The preliminary squirts began about 8 minutes before the eruption in the one he describes,‡ and the column reached a height of nearly 150 feet. He says also:

In every case the force of the ejection was much the same, but the duration of the premonitory and subsequent sputterings was quite variable. In the third eruption,

* Reconnaissance of Yellowstone River, Senate Ex. Doc. No. 66, 42d Congress, 2d sess., p. 30.

† Report U. S. Geol. Survey for 1872.

‡ Reconnaissance of Northwestern Wyoming, &c., by Capt. W. A. Jones, in 1873, p. 250.

given in the table [see table following], the first spurt occurred only 3 minutes before the ejection began, and the preliminary agitation in the fourth eruption took place but 2 minutes previously.

Dr. Heizmann found the temperature of the water at the base of the mound in pools to be 70° between the eruptions, while those about the vents (containing pebbles) had, just previous to an eruption, temperatures of 122°, 136°, and 138°.*

The following table is from Professor Comstock's report,† and to it I have added a column showing the intervals between the beginnings of the eruptions as in the table from my report for 1872, already given:

Table of Comstock's observations.

No. of eruption.	Date.	Eruption began.	Eruption ceased.	Duration.	Intervals between beginnings of eruptions.	Intervals of quiet.
	1873.	*h. m. s.*	*h. m. s.*	*m. s.*	*h. m. s.*	*h. m. s.*
1	Aug. 25	10 38 00 a. m.	10 43 00 a. m.	5 00	.....	.....
2	Aug. 25	11 36 00 a. m.	11 41 30 a. m.	5 30	0 58 00	0 53*00
3	Aug. 25	12 39 00 p. m.	12 44 00 p. m.	5 00	1 03 00	0 57 30
4	Aug. 25	1 41 15 p. m.	1 45 45 p. m.	4 30	1 02 15	0 57 15
5	Aug. 25	2 45 20 p. m.	2 50 00 p. m.	4 40	1 03 05	0 59 35
6	Aug. 25	3 53 35 p. m.	3 58 00 p. m.	4 25	1 08 15	1 03 35
7	Aug. 25	5 11 10 p. m.	5 15 40 p. m.	4 30	1 17 35	1 13 10†
8	Aug. 25	6 03 15 p. m.	6 07 45 p. m.	4 30	0 52 05	0 47 35‡
9	Aug. 25	7 12 00 p. m.	.....	.....	1 08 45	1 04 15
10	Aug. 25	8 14 00 p. m.	.....	.....	1 02 00	.....
11	Aug. 25	9 17 00 p. m.	.....	.....	1 03 00	.....
	Average duration and intervals			4 45§	1 03 48	0 59 29§

*In the original this is 58 minutes. I have recalculated the intervals from Comstock's data.
†In the original this is 0 hour 47 minutes 25 seconds.
‡In original this is 47.25.
§These averages, of course, are different from the original.

1874.—The Earl of Dunraven gives the heights to which the column is projected as from 100 to 150 feet for the space of about 5 minutes. While in action small jets and spurts of water were driven out from numerous points in the crack or fissure which traverses the mound.‡ The eruption described by him is like those already described.

1875.—In the report of E. S. Dana and G. B. Grinnell, Old Faithful is mentioned as follows:

Old Faithful, the guardian of the valley, showed a very high degree of regularity during the whole period of our stay.§ The interval between the commencement of the discharges was 65 or 66 minutes, and, as timed by us for nearly twenty-four successive eruptions, varied very slightly from this interval. The eruptions were of a very uniform character, differing but slightly in manner or duration (about 3 minutes) or in the amount of water thrown out. During the night we were roused each hour by the first rush of the water and steam, and certainly nothing could be more beautiful than this grand fountain in action, illuminated by the light of the full moon. The average height of the column of water, as determined by Mr. Wood, was 115 feet.‖

Captain Ludlow, in his report, gives the intervals as 65 minutes, and gives the height as over 100 feet.¶

*Reconnaissance of N. W. Wyoming, p. 303.
†*Ibid.*, p. 249.
‡Great Divide, p. 271.
§About 60 hours was the length of their stay.
‖Reconnaissance from Carroll, Mont., to Yellowstone National Park in 1875, p. 131.
¶*Ibid.*, pp. 26, 37.

1877.—General Sherman visited the Upper Geyser Basin in 1877, and speaks of Old Faithful as follows:

We reached the Upper Geyser Basin at 12 noon one day, and remained there till 4 p. m. of the next. During that time we saw the Old Faithful perform at intervals varying from 62 minutes to 80 minutes. The intervals vary, but the performance only varies with wind and sun. * * * So regular are its periods of activity that we could foretell its movement within a few minutes; sometimes we stood near enough to feel the hot spray, and at others we sat at our camp, about 300 yards away. Each eruption was similar, preceded by about 5 minutes of sputtering, and then would arise a column of hot water, steaming and smoking, to the height of 125 or 130 feet, the steam going a hundred or more feet higher, according to the state of the wind. It was difficult to say where the water ended and steam began, and this must be the reason why different observers have reported different results. The whole performance lasts about 5 minutes, when the column of water gradually sinks, and the spring resumes its normal state of rest.*

Colonel Poe says† that seven eruptions were observed, varying from 62 to 80 minutes, with an average period of about 67 minutes.

1878.—The eruptions noted by us were exactly like those seen by us in 1871 and 1872, and as observed by others. We were fortunate in obtaining a large number of its intervals, which are given in the following table. I am indebted to almost every member of the party for observations made while I was in other portions of the Basin. The heights are the heights of the column of water, and were obtained from angles taken with the gradienter, and the reason we took so few comparatively is due to the fact that the instrument was used a large part of the time in the triangulation:

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*General Sherman's tour of inspection, &c., in reports of inspection made in the summer of 1877. Washington, 1878, p. 36.

†*Ibid.*, p. 78.

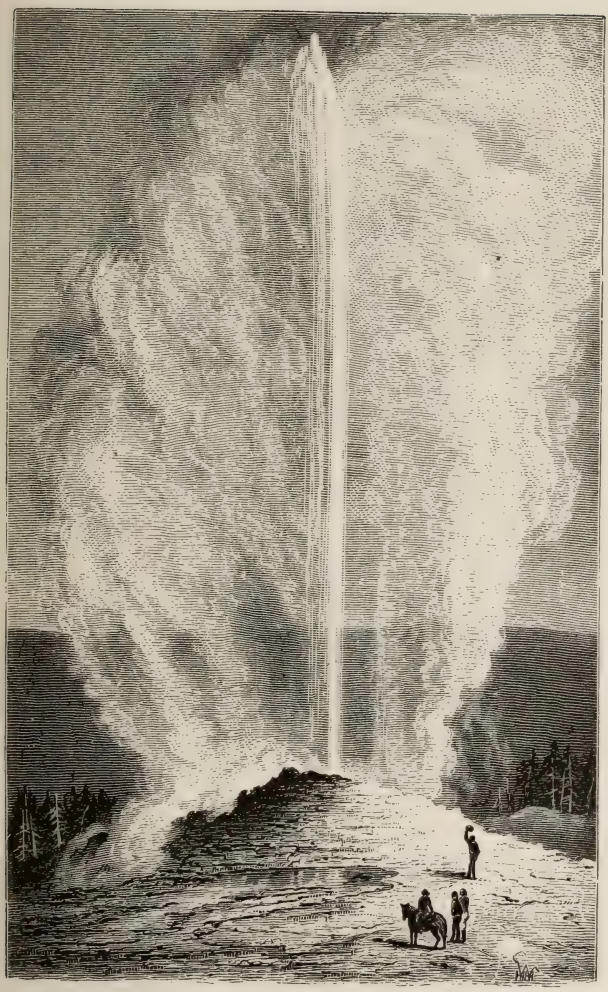

Fig. 10.—Old Faithful Geyser in action, 1871.

Number of eruption.	Date.	Preliminary spurts begin.	Number of preliminary spurts.	Eruption begins.	Maximum height is attained.	Eruption of water ceases.	Column begins to fall.	Intervals.						Entire duration.	Maximum height.
								Between beginnings of eruptions.	Of quiet from end of one water eruption to beginning of next.	From beginning of preliminary spurts to beginning of the eruptions.	From beginning of eruption to maximum.	From maximum to falling of column.	From falling of column to end.		
	1878.	*h. m. s.*		*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*Feet.*
1	Aug. 26.	Not taken	.....	4 45 00 p. m.	.....	4 49 00 p. m	.....	.....	.....	.....	.....	.....	.....	4 00	.....
2	Aug. 26.	Not taken	.....	5 53 00 p. m.	.....	5 58 00 p. m	.....	1 08 00	1 04 00	.....	.....	.....	.....	5 00	.....
3	Aug. 26.	Not taken	.....	7 11 00 p. m.	.....	7 16 00 p. m	.....	1 18 00	1 13 00	.....	.....	.....	.....	5 00	.....
4	Aug. 26.	Not taken	.....	8 16 00 p. m.	.....	8 21 00 p. m.	.....	1 05 00	1 09 00	.....	.....	.....	.....	5 00	.....
5	Aug. 27.	.....	.....	6 20 00 a. m.	.....	6 25 00 a. m.	.....	.....	.....	.....	.....	.....	.....	5 00	.....
6	Aug. 27.	.....	.....	7 30 00 a. m.	.....	7 35 00 a. m.	.....	1 10 00	1 05 00	.....	.....	.....	.....	5 00	.....
7	Aug. 27.	.....	.....	9 36 00 a. m.	.....	9 41 00 a. m.	.....	.....	.....	.....	.....	.....	.....	5 00	.....
8	Aug. 27.	.....	.....	10 40 00 a. m	.....	10 49 30 a. m.	.....	1 08 00	1 03 00	.....	.....	.....	.....	5 30	.....
9	Aug. 27.	.....	.....	11 45 00 a. m.	.....	11 49 30 a. m.	.....	1 05 00	0 55 30	.....	.....	.....	.....	4 30	.....
10	Aug. 27.	.....	.....	12 47 00 p. m	.....	12 51 30 p. m.	.....	1 02 00	0 57 30	.....	.....	.....	.....	4 30	139
11	Aug. 27.	.....	.....	5 14 20 p. m.	.....	5 18 45 p. m.	5 15 00	.....	.....	.....	.....	.....	.....	4 25	135
12	Aug. 27.	6 18 00	1	6 18 18 p. m.	6 19 00	6 22 50 p. m.	6 19 45	1 03 58	0 59 33	00 18	00 42	00 45	3 05	4 32	132
13	Aug. 27.	7 21 30 p. m.	5	7 25 55 p. m.	.....	7 30 20 p. m.	7 27 55	1 07 37	1 03 05	4 25	.....	.....	2 25	4 25	.....
14	Aug. 27.	8 22 30 p m.	6	8 29 51 p. m.	.....	8 35 00 p. m.	.....	1 03 56	0 59 31	7 21	.....	.....	.....	.....	.....
15	Aug. 27.	.....	.....	9 40 00 p. m.	.....	.....	.....	1 10 09	.....	.....	.....	.....	.....	.....	.....
16	Aug. 27.	.....	.....	10 41 00 p. m.	.....	.....	.....	1 01 00	.....	.....	.....	.....	.....	.....	.....
17	Aug. 28.	.....	.....	6 28 40 a. m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	Aug. 28.	7 25 30 a. m	8	7 33 15 a. m.	.....	.....	.....	1 04 35	.....	.....	.....	.....	.....	.....	.....
19	Aug. 28.	.....	.....	8 37 00 a. m.	.....	8 42 30 a. m	.....	1 03 45	.....	.....	.....	.....	.....	5 30	.....
20	Aug. 28.	9 27 55 a. m.	3	9 41 35 a. m.	.....	9 46 10 a. m.	9 41 56	1 04 35	0 59 05	3 40	.....	.....	4 14	4 35	.....
21	Aug. 28.	10 44 19 a. m.	9	10 50 05 a. m	.....	10 54 50 a. m.	10 51 45 a. m	1 08 30	1 03 55	5 46	.....	.....	3 35	4 45	132
22	Aug. 28.	11 52 45 a m	6	11 59 10 a. m	11 59 30 a. m.	12 04 00 p. m	12 00 10 p. m.	1 09 05	1 04 20	7 25	0 20	00 40	3 50	4 50	126
23	Aug. 28.	.....	.....	1 02 45 p. m	.....	.....	.....	1 13 35	1 08 45	.....	.....	.....	.....	.....	.....
24	Aug. 28.	2 11 00 p. m.	3	2 11 40 p. m	2 12 00 p. m	2 15 40 p. m.	2 12 40 p. m	1 09 05	.....	0 40	0 20	00 40	3 00	4 00	115
25	Aug. 28	.....	.....	3 12 00 p. m.	3 13 00 p. m.	3 16 50 p. m.	3 13 30 p. m.	1 00 20	0 56 20	.....	1 00	00 30	3 20	4 50	121
26	Aug. 28.	4 12 20 p. m.	2	4 12 35 p. m.	4 12 40 p. m.	4 16 15 p. m.	.....	1 00 35	0 55 45	0 15	0 05	.....	.....	3 40	106
27	Aug. 28.	5 11 15 p. m.	8	5 17 58 p. m.	.....	5 22 30 p. m.	5 18 55 p. m.	1 05 23	1 01 43	6 43	.....	.....	3 35	4 32	118
28	Aug. 28.	6 24 35 p. m.	5	6 25 11 p. m.	.....	6 29 30 p. m.	6 26 55 p. m.	1 07 13	1 02 41	0 36	.....	.....	2 35	4 19	133
29	Aug. 28.	7 29 05 p. m.	2	7 29 20 p. m	.....	7 34 10 p. m.	7 30 15 p. m.	1 04 09	0 59 50	0 15	.....	.....	3 55	4 50	.....

Table of observations on Old Faithful—Continued.

Number of eruption.	Date.	Preliminary spurts begin.	Number of preliminary spurts.	Eruptions begins.	Maximum height is attained.	Eruption of water ceases.	Column begins to fall.	Intervals.						Entire duration.	Maximum height.
								Between beginning of eruptions.	Of quiet from end of one water eruption to beginning of next.	From beginning of preliminary spurts to beginning of the eruptions.	From beginning of eruption to maximum.	From maximum to falling of column.	From falling of column to end.		
	1878.	*h. m. s.*		*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*Feet.*
30	Aug. 28	.....	.....	8 29 30 p. m.	.....	.....	.....	1 00 10	0 55 40	.....	.....	.....	.....	.....	.....
31	Aug. 28	.....	.....	9 37 30 p. m.	.....	.....	.....	1 08 00	.....	.....	.....	.....	.....	.....	.....
32	Aug. 29	.....	.....	6 20 00 a. m.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33	Aug. 29	.....	.....	7 23 00 a. m.	.....	7 27 40 a. m	.....	1 03 00	.....	.....	.....	.....	.....	4 40	118
34	Aug. 29	8 24 00 a. m.	12	8 34 40 a. m.	8 35 00 p. m.	8 39 10 a. m.	.....	1 11 40	1 07 40	10 40	0 20	.....	.....	4 30	.....
35	Aug. 29	9 36 10 a. m.	5	9 38 20 a. m.	9 38 50 p. m.	9 43 25 a. m.	9 39 20 p. m.	1 03 40	0 59 10	2 20	0 30	0 30	4 05	4 05	.....
36	Aug. 29	10 38 00 a. m.	8	10 43 43 a. m.	10 44 40 p. m.	10 48 10 a. m.	.....	1 04 23	1 00 18	5 43	0 57	.....	.....	4 27	.....
37	Aug. 29	11 44 20 a. m.	10	11 56 55 a. m.	11 57 15 p. m.	12 1 25 p. m.	11 57 40 p. m.	1 13 12	1 08 45	12 35	0 20	0 25	3 45	4 30	.....
38	Aug. 29	12 56 00 p. m.	9	1 01 55 p. m.	1 02 30 p. m.	1 06 40 p. m	1 03 00 p. m.	1 05 00	1 00 30	5 55	0 35	0 30	3 40	4 45	.....
39	Aug. 29	.....	.....	2 04 00 p. m.	.....	.....	.....	1 02 05	0 57 20	.....	.....	.....	.....	.....	.....
40	Aug. 29	3 01 00 p. m.	12	3 07 25 p. m.	3 07 46 p. m.	3 11 55 p. m.	3 08 15 p. m.	1 03 25	.....	6 25	0 15	0 35	3 40	4 30	.....
41	Aug. 29	.....	.....	4 09 58 p. m.	.....	4 14 35 p. m.	.....	1 02 33	0 58 03	.....	.....	.....	.....	4 37	.....
42	Aug. 29	.....	.....	5 18 00 p. m.	.....	5 22 00 p m.	.....	1 08 02	1 03 25	.....	.....	.....	.....	.....	.....
43	Aug. 29	.....	.....	6 17 00 p. m.	.....	6 21 35 p. m.	.....	0 59 00	0 55 00	.....	.....	.....	.....	.....	.....
44	Aug. 29	7 14 00	12	7 26 10 p. m.	.....	7 30 30 p. m.	.....	1 09 10	1 04 35	12 10	.....	.....	.....	.....	.....
45	Aug. 29	.....	.....	8 20 14 p. m.	.....	.....	.....	0 54 04	0 49 44	.....	.....	.....	.....	.....	.....
46	Aug. 30	.....	.....	7 06 40 a. m.	.....	7 11 25 a. m.	.....	.....	.....	.....	.....	.....	.....	4 45	.....
47	Aug. 30	8 07 15	12	8 14 16 a. m.	8 14 35	8 18 35 a. m.	8 15 30 a. m.	1 07 36	1 02 51	7 01	0 19	0 55	3 05	4 19	.....
48	Aug. 30	9 12 55	11	9 17 58 a. m.	9 18 10	9 22 40 a. m.	9 18 35 a. m.	1 03 42	0 59 23	5 03	0 12	0 25	4 05	4 42	.....
49	Aug. 30	.....	.....	10 24 00 a. m.	.....	10 28 30 a. m.	.....	1 06 02	1 01 20	.....	.....	.....	.....	4 30	.....
50	Aug. 30	.....	.....	11 28 15 a. m.	.....	11 33 00 a. m.	.....	1 04 15	0 59 45	.....	.....	.....	.....	4 45	.....
51	Aug. 30	.....	.....	12 38 00 p. m.	.....	12 42 00 p. m.	.....	1 09 45	1 05 00	.....	.....	.....	.....	4 00	.....
52	Aug. 30	.....	.....	1 39 40 p. m.	.....	1 45 40 p. m.	.....	1 01 40	0 57 40	.....	.....	.....	.....	5 20	.....
53	Aug 30	.....	.....	2 49 30 p. m.	.....	.....	.....	1 09 50	1 03 50	.....	.....	.....	.....	.....	.....
54	Aug. 30	.....	.....	3 51 00 p. m.	.....	.....	.....	1 01 30	.....	.....	.....	.....	.....	.....	.....
55	Aug. 30	.....	.....	5 00 30 p. m.	.....	5 05 00 p. m.	.....	1 09 30	.....	.....	.....	.....	.....	4 30	.....
56	Aug. 30	.....	.....	6 02 30 p. m.	.....	6 06 10 p. m.	.....	1 02 00	0 57 30	.....	.....	.....	.....	3 40	.....
57	Aug. 30	.....	.....	7 12 10 p. m.	.....	.....	.....	1 09 40	1 06 00	.....	.....	.....	.....	4 35	.....
58	Aug. 30	.....	.....	8 15 15 p. m.	.....	.....	.....	1 03 05	0 58 30	.....	.....	.....	.....	.....	.....
59	Aug. 30	.....	.....	9 20 00 p. m.	.....	.....	.....	1 04 45	.....	.....	.....	.....	.....	.....	.....

63	Aug. 31	.....	.....	1 38 00 ...	.....	.....	.....	.....	1 05 00	.....	.....	.....	.....	.....	.....	.....	.....
64	Aug. 31	.....	.....	2 50 00 a. m.	.....	.....	.....	.....	1 12 00	.....	.....	.....	.....	.....	.....	.....	.....
65	Aug. 31	.....	.....	3 52 00 a. m.	.....	.....	.....	.....	1 01 00	.....	.....	.....	.....	.....	.....	.....	.....
66	Aug. 31	.....	.....	4 55 00 a. m.	.....	.....	.....	.....	1 03 00	.....	.....	.....	.....	.....	.....	.....	.....
67	Aug. 31	.....	.....	6 05 00 a. m.	.....	.....	.....	.....	1 10 00	.....	.....	.....	.....	.....	.....	.....	.....
68	Aug. 31	.....	.....	7 07 25 a. m.	7 08 00 a. m.	7 11 45 a. m.	7 08 15 a. m.	.....	1 02 25	.....	.....	0 35	0 15	3 30	4 20	.....	.....
69	Aug. 31	.....	.....	8 13 21 a. m.	.....	8 18 00 a. m.	.....	.....	1 05 56	1 01 36	.....	.....	.....	.....	4 39	106	.....
70	Aug. 31	.....	.....	9 19 00 a. m.	.....	9 23 30 a. m.	.....	.....	1 05 39	1 01 00	.....	.....	.....	.....	4 30	.....	.....
71	Aug. 31	.....	.....	10 17 30 a. m.	10 19 00 a. m.	10 22 00 a. m.	.....	.....	0 58 30	0 54 00	.....	00 30	.....	.....	4 30	88	.....
72	Aug. 31	11 20 00 a. m.	2	11 24 00 a. m.	11 25 00 a. m.	11 28 30 a. m.	11 25 10 a. m.	.....	1 06 30	1 02 00	4 00	1 00	0 10	3 20	4 30	105	.....
73	Aug. 31	12 25 10 p. m.	2	12 26 30 p. m.	12 27 15 p. m.	12 31 30 p. m.	12 27 30 p. m.	.....	1 02 30	0 58 00	1 20	0 45	0 15	4 00	5 00	110	.....
74	Aug. 31	1 25 45 p. m.	6	1 31 40 p. m.	1 32 15 p. m.	1 36 00 p. m.	1 32 45 p. m.	.....	1 05 10	1 00 10	5 55	0 35	0 30	3 15	4 20	114	.....
75	Aug. 31	2 28 50 p. m.	4	2 33 20 p. m.	2 34 15 p. m.	.....	.....	.....	1 01 40	0 57 20	4 30	0 55	.....	.....	.....	104	.....
76	Aug. 31	3 32 20 p. m.	3	3 36 25 p. m.	3 37 10 p. m.	3 41 16 p. m.	3 37 30 p. m.	.....	1 03 05	.....	4 05	0 45	0 20	3 45	4 50	103	.....
77	Aug. 31	4 40 30 p. m.	3	4 41 50 p. m.	4 42 40 p. m.	4 46 20 p. m.	4 43 00 p. m.	.....	1 05 25	1 00 35	1 20	0 50	0 40	3 20	4 30	102	.....
78	Aug. 31	.....	.....	6 49 40 p. m.	.....	6 53 30 p. m.	.....	.....	.....	.....	.....	.....	.....	.....	3 50	.....	.....
79	Aug. 31	.....	.....	8 55 45 p. m.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
80	Aug. 31	.....	.....	9 55 40 p. m.	.....	.....	.....	.....	0 59 55	.....	.....	.....	.....	.....	.....	.....	.....
81	Aug. 31	.....	.....	10 56 30 p. m.	.....	.....	.....	.....	1 00 50	.....	.....	.....	.....	.....	.....	.....	.....
82	Sept. 1	.....	.....	6 29 30 a. m.	.....	6 33 55 a. m.	.....	.....	.....	.....	.....	.....	.....	.....	4 25	.....	.....
83	Sept. 9	.....	.....	9 55 15 a. m.	.....	9 59 50 a. m.	.....	.....	.....	.....	.....	.....	.....	.....	4 35	.....	.....
84	Sept. 9	.....	.....	11 04 00 a. m.	.....	11 08 30 a. m.	.....	.....	1 08 45	1 04 10	.....	.....	.....	.....	4 30	.....	.....
85	Sept. 9	.....	.....	12 06 20 p. m.	.....	.....	.....	.....	1 02 20	0 57 50	.....	.....	.....	.....	.....	.....	.....
86	Sept. 9	.....	.....	3 22 45 p. m.	.....	3 27 15 p. m.	.....	.....	.....	.....	.....	.....	.....	.....	4 30	.....	.....
87	Sept. 9	.....	.....	4 32 50 p. m.	.....	4 37 00 p. m.	.....	.....	1 00 05	0 55 35	.....	.....	.....	.....	4 10	.....	.....
88	Sept. 9	.....	.....	5 37 30 p. m.	.....	5 42 00 p. m.	.....	.....	1 04 40	1 00 30	.....	.....	.....	.....	4 30	.....	.....
89	Sept. 9	.....	.....	6 42 30 p. m.	.....	6 46 30 p. m.	.....	.....	1 05 00	1 00 30	.....	.....	.....	.....	4 00	.....	.....
90	Sept. 10	.....	.....	9 30 45 a. m.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
91	Sept. 10	.....	.....	10 32 20 a. m.	.....	.....	.....	.....	1 01 35	.....	.....	.....	.....	.....	.....	.....	.....
92	Sept. 10	.....	.....	11 40 22 a. m.	.....	.....	.....	.....	1 08 02	.....	.....	.....	.....	.....	.....	.....	.....
93	Sept. 10	.....	.....	12 44 00 p. m.	.....	.....	.....	.....	1 03 38	.....	.....	.....	.....	.....	.....	.....	.....
94	Sept. 10	.....	.....	1 47 00 p. m.	.....	.....	.....	.....	1 03 00	.....	.....	.....	.....	.....	.....	.....	.....
95	Sept. 10	.....	.....	2 53 30 p. m.	.....	.....	.....	.....	1 06 30	.....	.....	.....	.....	.....	.....	.....	.....
96	Sept. 10	.....	.....	4 00 35 p. m.	.....	.....	.....	.....	1 07 05	.....	.....	.....	.....	.....	.....	.....	.....
97	Sept. 10	.....	.....	5 01 30 p. m.	.....	.....	.....	.....	1 00 55	.....	.....	.....	.....	.....	.....	.....	.....
Average									1 05 06$\frac{23}{28}$	0 59 29$\frac{7}{8}$	4 22$\frac{2}{5}$	0 33$\frac{7}{21}$	0 30$\frac{5}{18}$	3 30$\frac{2}{11}$	4 35$\frac{5}{12}$	116′ 43$\frac{1}{3}$″	

NOTE.—The lines across the table separate the observations so as to show at a glance those that are consecutive.

Eruptions Nos. 1 to 10, inclusive, were noted by Dr. Hayden.

Eruptions Nos. 49 to 55, inclusive, and No. 57 were noted by M Richardson.

Eruptions Nos. 59 to 67, inclusive, were noted by Mr. Eccles.

Eruptions Nos. 69 to 77, inclusive, were noted by Mr. Ladd.

The heights given by Mr. Ladd are perhaps a little too low. It somewhat difficult to obtain the exact height unless one has been acc tomed to distinguish between the steam and column of water.

The heights in all cases represent the distance from the top of t crater to the top of the column. They were measured with the gra entor, which is the reason so few comparatively were taken, as the strument was frequently in use for the topographical work. The du tion is from the beginning until the escape of steam alone shows th the water period is over. The duration of some is not given as our d tance from the geyser at times prevented our obtaining it. The av age duration of the steam period, as determined from 5 observations, 60 seconds.

Four of the intervals given in this table are below 60 minutes a eight over 70 minutes, the range being from 54 minutes 4 seconds to minutes. Neither the long nor the short intervals occur with any re ularity, nor do they appear to influence the duration of the eruptio The greatest and the smallest elevation of the column have nearly t same duration. The twelfth eruption had a duration of 4 minutes a 25 seconds, and the column reached the height of 135 feet, while t seventy-first eruption reached a height of only 88 feet and had a du tion of 4½ minutes—just five seconds longer. The shortest duration w 3 minutes and 40 seconds on the twenty-sixth and fifty-sixth eruptio and the height of the column was 106 feet in the former. The longe duration was 5½ minutes, but no height taken; but in the seventy-thi eruption the duration was 5 minutes and the height of the column w 110 feet. These heights were all carefully taken to the top of the colu of water, and are the heights above the top of the cone. At no ti was the crater observed to be full of water, and immediately after t eruptions the water sinks or disappears and steam escapes. There not, however, the violent steam period that is noted in the Castle; t steam from Old Faithful escapes very gently after the column sinks.

The fifty-sixth eruption noted in the table above occurred August 3 at 6.30 p. m. At 5.30 p. m. the crater was visited and found entire empty. Steam was coming gently from the orifice about 5 feet down the crater and the maximum thermometer held in this registered 199° At 5.50 p. m. water began to spurt into the crater with puffs of stea and the temperature registered was 200° F. These spurts became high and higher until they splashed over the side of the crater. They al came closer together, and at 5.56½ p. m. spurted 5 feet above the to Five temperatures were taken, all being 200° F. The last one was ju four and a half minutes before the eruption began. The pools outsi just after the eruption had a temperature of 170° F. This was the wat that had fallen from the column and had been cooled by contact wi the air. The theoretical boiling point here is 199°, so that we have temperature above the boiling point caused, probably, by the heating the water during the escape of the superheated steam from far down the tube of the geyser. It was impossible to obtain the temperature the water while the geyser was in action, but it was probably great than 200°.

1879.—Mr. Norris, the superintendent of the Park, thinks that the i

ervals of Old Faithful had increased in 1879. In his report for that ear (page 17) he says:

Old Faithful, though still the favorite geyser, has certainly lost prestige by an occasional prolongation of its intervals between eruptions of from 5 to 15 or 20 minutes uring the extreme dry weather of the past season; but whether it is temporary for ant of water, or permanent from change of supply fissures or other causes unknown, me alone will determine.

He, however, gives no data, and we have already seen that the length f the interval may have a range of nearly 24 minutes.* Dr. S. Weir Iitchell, who was in the Upper Geyser Basin in 1879, gives the average me of the eruptions observed by him at 70 minutes,† which is only bout 5 minutes greater than the average of the eruptions observed in 878. He may have observed only a few eruptions, and they may have ad exceptionally long intervals. I think that the data are insufficient o show that the geyser is becoming less active, although in the course f time it may follow the example of the Castle, and as its cone becomes rger its intervals may become longer, and a roaring steam period be eveloped.

The following table contains the results of the observations made in ie different years, which are thus brought together for the purpose of omparison:

Table of comparison of observations on Old Faithful Geyser.

Year.	Observer.	No. of eruptions observed.	Intervals.			Average duration.	Maximum height of column.
			Minimum.	Maximum.	Average.		
			m. s.	*m. s.*	*m. s.*	*m. s.*	*Feet.*
70	Lieutenant Doane	.....	.....	.....	50. 0	5. 00	125
70	Washburne	.....	.....	.....	60. 0	not given.	75
71	Barlow	.....	.....	.....	.....	.....	138*
72	Peale	17	65. 0	70. 34	67. 54	4. 53	130*
73	Comstock	11	52. 5	77. 35	63. 48	4. 45	nearly 150
74	Dunraven	.....	.....	.....	.....	5. 00	100–150
75	Dana and Grinnell	24	.....	.....	65. 0 to 66. 0	about 3. 00	115*
77	General Sherman and Colonel Poe	7	62. 0	80. 0	67. 0	5. 00	125–130
8	Peale	97	54. 4	78. 0	65. 6	4. 35	135*
9	Mitchell	.....	.....	.....	70. 0	5. 00	150
9	Professor Geike	.....	.....	.....	.....	5. 00	120
0	Seguin	.....	.....	.....	45. 0	4 to 5. 00	197
1	Norris	.....	.....	.....	.....	5. 00	175

* These heights were measured.

UPPER SPRINGS.

Above Old Faithful and the Giantess Group the springs are few in umber and are located on the east side of the Fire Hole River. I have esignated them as the Upper Springs simply for convenience. There re half a dozen basins of small size and one small geyser that spouts bout 3 feet. The deposits are brilliant in color, but the springs do not erit more than a reference. Above these the valley narrows to a deep,

* In 1881 Prof. Norris says Old Faithful had hourly eruptions of five minutes' duraon, the columns of water reaching a height of 175 feet. See his Report for 1881, 56.

† Lippincott's Magazine, June, 1880, page 702.

impassable cañon, with nearly vertical walls, and no springs are m with until the Third Geyser Basin is reached.

THE GIANTESS GROUP.

This group of springs includes two of the most powerful geysers the Upper Basin and many interesting springs. The mound of si ceous sinter upon which they are located is on the north side of the riv immediately opposite Old Faithful Group. The Fire Hole River ente the basin, flowing almost due north. It very soon turns and flows wes ward between the Giantess and Old Faithful Groups, and after passi the latter turns to the northward along the western side of the latt Tlre group is very compact, occupying an area of about 22 acres. Th area is covered with the siliceous deposits in laminæ, as though orig nally there had been one immense spring which built the mound, a on dying out had given rise to the many springs that now exist over i surface. The Bee Hive, New Geyser, and Trinity are the geysers ha ing cones or craters. The Giantess would not ordinarily be taken for geyser. As the following table shows, about 46 springs were examine

Table of Giantess Group.

Name and number.	Size and depth.	Surface and other temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.			
Giantess Geyser	34 by 24 feet	Surface, 199; 12 feet below the surface, 201.	4 p. m.		See text for compl notes.
Bee Hive Geyser	Cone is 3 feet high, 3 by 4 feet on top, orifice is 2 by 3 feet, 21 feet deep.	5 feet below top of cone, 200; 15 feet below top of cone, 204.			See text for compl notes.
1	10½ by 11½ feet, 14 feet deep.	Surface, 175; 12 feet below the surface, 186.			Deep-blue sprin with scalloped ed on high mound.
2	Fissure 4 feet long				Yellow sputterer.
3	5 by 6 feet	Surface, 145			Quiet inkish pool.
4	Basin 15 by 18 feet, spring 8 by 8 feet.	Surface, 193			Crater-like hole which the water 6 feet below t surface.
5	8 by 11½ feet, 16 feet deep.	Surface, 180; 15 feet below surface, 198.			Bluish-gray basi bubbles at one si
6. Vault Spring	17 feet by 5 to 10 feet, 9 feet deep at one end, 13 feet at the other.	Surface, 172; 12 feet deep, 173.			Oblong spring on t platform of t Giantess.
7	11 by 7½ feet, 12 feet deep, rim 18 inches high.	Surface, 197; 11 feet deep, 205.			Boiling spring wi inky-hued water
8	6½ feet long, 12 feet deep.	Surface, 195; 11 feet deep, 203.			Active spouter.
8 *a*	2 feet drain	Surface, 194			Near No. 8 water 2 feet below the to
9	4 by 4 feet	Can't be taken			Yellow spouter.
10	6½ by 8 feet	163			Water is 9 feet bel surface in a ragg purplish crater.
11	2 feet diameter	182			Yellow crater-li hole.
12	Basin with two holes. *a* is 10 by 14 feet, *b* is 9 by 18 feet, 8 feet deep in deepest place.	Surface, 176; 7 feet deep, 191.			This spring has beautiful red, y low, and salmo colored lined wat outlet.
13	3 feet diameter	162			Small pool close to
14	4 by 6 feet	5 feet down the temperature is 150.			White crater ceives water fr overflow of Gia tess.

Table of Giantess Group—Continued.

ame and number.	Size and depth.	Surface and other temperatures.	Time of observation.	Temperature of air.	Remarks.
		°F.			
.....	10 by 14 feet	Surface, 189	.....	----	Light-yellow bulger, spouts at intervals; near it is empty hole 8½ by 9 feet.
.....	4½ by 6½ feet	.....	.....	----	In the water-way from No. 10.
.....	Triangular, 10 feet on sides.	179 at surface	.....	----	White-lined pool.
.....	Large basin with orifice, 3 inches by 1 foot.	.....	.....	----	Empty when observed.
.....	7 by 8½ feet	138	.....	----	White pool which bubbles slightly.
.....	7 by 9 feet	182	.....	----	Rusty-edged boiler with dark basin in which water appears black.
.....	*a* 11 feet diameter, *b* 13 by 16 feet.	*a* 112; *b* 136	.....	42	*a* has been a geyser; it is greenish turbid. *b* is grassy-edged pool nearly square.
.....	7½ by 2 to 3 feet	181	.....	----	Boiling spring with beaded edge 9 inches high and sloping in towards center of spring.
.....	Basin 16 by 24 feet, spring 6½ by 9 feet.	159	.....	----	Flat basin of geyserite with detached blocks.
.....	*a* 4 by 3 feet, *b* 2½ by 3 feet.	*a* 164	.....	----	*a* is a boiling spring, and *b* is a quiet hole.
inity Geysers..	*a* orifice 8 by 10 inches, on mound a foot to 18 inches high, 4 to 6 inches deep; *b* 11 by 4 feet, mound is 2 feet high, general depth 7 feet; *c* cone 2½ feet high, orifice about 3 feet long.	*a* 163; *b* surface, 188; *c* surface, 180.	.....	----	All on the same platform; for further notes see text following table.
obe Geyser....	Cone 4 feet high, orifice 18 inches by 2½ feet.	Surface, 199	10.15 a. m.	36	
.....	*a* 7 by 10 feet, 7 feet deep, fissure at the bottom 2 by 5 feet; *b* 7 by 8 feet, small orifice.	*a* surface, 176; 6 feet below surface, 192; *b* surface, 141.	.....	----	Double spring, two orifices in one basin: *a* is the principal spring.
.....	3 by 3 feet	Surface, 141	.....	----	Small triangular geyser-like cone.
.....	9 by 11 feet, inside it is 6½ by 7 feet.	176	.....	----	Beautiful white basin.
.....	Fissure 6 feet by 18 inches to 2 feet.	185	.....	----	Water has slight milky hue.
.....	6 by 7 feet	181	.....	----	Violent bulger, throws water a foot or two.
.....	Outside is 12 by 13 feet, inside 5 by 5½ feet, 6 feet deep.	Surface, 180; 5 feet below surface, 201.	.....	----	Water comes out in great bulges, throwing the basin full into waves.
.....	Whole size is 43 by 21 feet and 34 feet; *a* is 21 by 24½ feet, *b* is 34 by 23½ feet; *a* is 13 feet deep, *b* is 12 feet deep.	*a* surface, 182; 12 feet below the surface, 189. *b* surface, 176; 4 feet below the surface, 182.	.....	----	Double spring; *b* is a green pool; *a* throbs occasionally.
.....	7½ by 10 feet, 15 feet deep.	Surface, 177; 14 feet below surface, 185.	.....	----	Greenish turbid pool in white basin.
.....	3½ by 8 feet	Cool	.....	----	Red pool, receives water from springs above.
.....	.....	.....	.....	----	Old geyser hole.
.....	2 by 3 feet	186	.....	----	Yellow boiling hole.

Table of Giantess Group—Continued.

Name and number.	Size and depth.	Surface and other temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.			
36	8 by 14 feet	159			Irregular wh holes.
37					Old crater, with water.
38	Basin 1 foot by 18 inches, orifice 3 inches diameter.				Small geyser, wa out of sight.
39	2 feet diameter	149			White hole.
40	6 feet diameter	177			Bulger.
41	3 by 3½ feet	177			This is a very pe liar spring. La bubbles esca from orifice at b tom of spring, b do not appear reach the surfa
42		*a* 173			Double basin w three orifices; *a* quiet, *b* and *c* bulgers and sp constantly, see ing to be indepe ent of *a*.
43	Triangular with sides 3 feet.	163			Small pool.

NOTE.—Where temperatures are not marked either surface or deep, they are surface temperatur

DESCRIPTION.

Giantess Geyser.—This geyser, named in 1870 by the Washburn part although comparatively insignificant as regards its crater, is one of th most magnificent in action, as described by those who have seen it full activity. The eruptions that have been witnessed are four in nu ber, and it is probable that the periods of quiescence are long in the duration. The crater or basin (Fig. 1, Plate XXIII) is irregular in shap measuring 34 feet in its greatest length and 24 feet in its widest portio and is on the summit of the mound or terrace. It has a broad, gent sloping mound of deposit about 200 yards in diameter at the base. The is no elevated rim, but the upper layer of the surrounding laminate geyserite projects over the basin, which has a depth of 63 feet. It remarkable for the absence of the handsome ornamentation that is us ally seen about the geysers. There is little either in its structure surroundings to indicate its power. The water in the geyser has a dee clear, bluish-green tint. The description of the eruption will be obtain best from those who have witnessed them under favorable circumstance

1870.—The Washburn party were fortunate enough to see the Gian ess in action, and the following description is by Mr. N. P. Langford:

No water could be discovered, but we could distinctly hear it gurgling and boilin at a great distance below. Suddenly it began to rise, boiling and spluttering, an sending out huge masses of steam, causing a general stampede of our company, dri ing us some distance from our point of observation. When within about 40 feet the surface it became stationary, and we returned to look down upon it. It was foam ing and surging at a terrible rate, occasionally emitting small jets of hot water near to the mouth of the orifice. All at once it seemed seized with a fearful spasm, an rose with incredible rapidity, hardly affording us time to flee to a safe distance, whe it burst from the orifice with terrific momentum, rising in a column the full size this immense aperture to the height of 60 feet; and through and out of the apex this vast aqueous mass five or six lesser jets or round columns of water, varying size from 6 to 15 inches in diameter, were projected to the marvelous height of 2

eet. These lesser jets, so much higher than the main column and shooting through , doubtless proceed from auxiliary pipes leading into the principal orifice near the ottom, where the explosive force is greater. * * * This grand eruption con- nued for twenty minutes, and was the most magnificent sight we ever witnessed. Ve were standing on the side of the geyser nearest the sun, the gleams of which filled ie sparkling columns of water and spray with myriads of rainbows, whose arches ere constantly changing—dipping and fluttering hither and thither and disappear- ng only to be succeeded by others, again and again, amid the aqueous column, while ie minute globules into which the spent jets were diffused when falling sparkled like shower of diamonds, and around every shadow which the denser clouds of vapor, in- rrupting the sun's rays, cast upon the column, could be seen a luminous circle radiant ith all the colors of the prism, and resembling the halo of glory represented in paint- ngs as encircling the head of Divinity. All that we had previously witnessed seemed me in comparison with the perfect grandeur and beauty of this display. Two of ese wonderful eruptions occurred during the twenty-two hours we remained in the alley. This geyser we named The Giantess.*

1871.—We were in the Upper Basin in 1871 from the evening of Au- ust 4 until the morning of August 6, and during this time it was not een in action. Colonel Barlow's party this same year spent three days here, but during this time no member of his party saw it in action, lthough he himself thought that during the last night of his stay it layed, as he heard heavy concussions from some point in that direction.

1872.—The only eruption witnessed by us in 1872 was on the evening f August 18, when it was too dark to see the full grandeur of its action. his eruption consisted of three distinct periods of spouting as follows:

No. 1.—Eruption began at 6.56.30 p. m., lasted 17 minutes.

No. 2.—Eruption began at 7.43.30 p. m., lasted 17 minutes.

No. 3.—Eruption began at 8.48.30 p. m., end not taken.

There was an immense mass of water thrown up which surged and plashed in all directions, with jets passing through it at intervals. here were about 73 pulsations under ground per minute. This de- reased toward the end. Professor Bradley noted the occurrence of ve or six pulsations before the eruption began. During the first period ngles for the height were taken from the end of a base line of 200 feet, nd the highest jets were found to reach a height of 39 feet, the steam oing to about 69 feet. The average height of the mass of water was) feet. It is probable that during the succeeding periods the height as greater, but it was too dark to take any angles. The end of the st period was not taken. The day after it was ended the water was) feet below the surface. On the second day (August 20, 1872) I took e temperature at 11.50 a. m., and found it to be 192° F. at the edge, e air being 56° F. The water was level with the rim and perfectly iet. Before the eruption it was in constant agitation, and one seeing only then would have supposed it to be a constantly boiling spring. It not known how long after the eruption this boiling begins.

1873.—There is no record of this geyser having been seen in action uring 1873 by Professor Comstock, but E. J. Stanley saw it in action, lthough he says "it positively refused to give us one of its grandest isplays."†

1874.—The Earl of Dunraven, who visited the Basin in 1874, describes ie geyser, but does not mention having seen it in operation.

1875.—The members of Captain Ludlow's expedition to the Park wit- essed an eruption, and I insert the very full description from the re- ort of Dana and Grinnell:

When we arrived, August 21, the crater was quite full and bubbling, seeming to omise a speedy eruption. The following day, at 6.30 a. m., it boiled up vigorously,

* Scribner's Monthly, Vol. II, 1871, p. 125.

† Rambles in Wonderland. By Edwin J. Stanley. New York, D. Appleton & Co., 873. p. 103.

throwing up jets a few feet into the air, exciting hopes that it was about to perfor and bringing those who were in camp somewhat hastily across the stream. At 9 o'clo it boiled up again, at times throwing out considerable water, so that it was near empty as far as we could see, looking far down into the crater. It rapidly filled, ho ever, and a second outburst on a small scale took place. Two hours later a more vi orous display commenced, the hot water being thrown to a height of 100 feet, by series of successive irregular throbs, like the beats of a pump; the heavy thumpi going on below in a startling manner. This irregular display, extremely interesti and beautiful, yet nothing compared with what the Giantess is said to do, lasted one hour; the entire volume of water thrown out being very great. At length, wi a sudden burst, the steam drove up the water to a much greater height than bef seen, the noise and concussions accompanying the outburst being very violent. T water was kept at its greatest height for two or three minutes, and for this time found the Giantess all that had been claimed for it. But the reservoir was almost e hausted, and in a short time the only escape was a mass of steam, which rushed o of the crater with a force which no words could describe. * * * This steam cape lasted for an hour without any sensible diminution in violence, and we could help regretting that all the water had been ejected before the most powerful burst steam had begun, so that we might have had a full display of the power that was hand acting on the water. The conception of force given by this great steam esca was perhaps even greater than if it had taken merely the form of a fountain. S hours later the steam was still escaping, though with somewhat diminished energ and an occasional liquid jet seemed to show that a little water was draining into t reservoir, only to be immediately ejected.*

I can find no record of any spouting in 1876 or 1877.

1878.—I reached the Upper Geyser Basin on the afternoon of Augu 27, and remained until the morning of September 2, and during th my first visit, the Giantess was quiet. We were camped immediate opposite the mound, and had an eruption taken place during the nig we could scarcely have missed hearing it. In the morning before arrival an eruption was noted from a distance, but the notes we meager. It began about 8.45 a. m., and was followed by a second spu at 10.48 a. m. The first lasted 9 minutes, and the second 13. On Se tember 1 the surface temperature was 199° F., and at a depth of feet 201° F. The water appeared to be in constant ebullition. O second visit was from the evening of September 8 until the afternoon September 11. During this visit no change was observed in the con tion of the Giantess, and we left the Basin without having seen it action.

From the descriptions that have been given, it is evident that t eruption of this geyser is divided into three distinct periods. Lan ford probably saw it after the first was ended, for he found the crat or bowl empty, and Doane, speaking of the geyser, says:

> This grand geyser played three times in the afternoon, but appears to be irregu in its periods, as we did not see it in eruption again while in the valley.†

He does not give any idea as to the interval separating these eru tions. In the eruption witnessed by myself in 1872, the interval tween the first and second periods was 47 minutes, and between t second and third 1 hour and 5 minutes, the interval between the fi and third being 1 hour and 52 minutes, which is nearly that observ by Grinnell and Dana, namely, 2 hours. They, however, do not gi the duration of the two preliminary periods, which, in the case of t eruption noted in 1872, was 17 minutes for each. Dana and Grin noticed preliminary attempts 2½ hours before the eruption and give t length of the steam period following it as over 6 hours.

As to the interval between the eruptions, the observations are too f in number to determine much. It is, however, undoubtedly long. Wh

* Report of a Reconnaissance from Carroll, Mont., to Yellowstone National Park, & 1875, 1876, pp. 131, 132.

† Report of Yellowstone Expedition of 1870, p. 32.

ıptain Ludlow's party examined it it was "known not to have played r some weeks." They found it boiling gently the day before the erup-ın, and giving off clouds of steam.

Bee Hive Geyser.—This geyser is 400 feet from the Giantess, on a ver level, about 100 feet from the river. It is readily distinguished its cone, from the shape of which it derived its name in 1870, when was first described by the Washburn party. This cone or crater is 3 t in height, and almost circular, measuring 3 by 4 feet on top, and ving a circumference of 20 feet at the base. It is beautifully coated th beaded silica, which in many places has a pearly aspect. There is surrounding terraced deposit, as there is about most of the craters ıis is probably due to the fact that very little water falls around it. ıe orifice on the summit of the cone measures 2 feet by 3 feet, and the ıe dropped into the tube reached a depth of 21 feet. Just outside of e cone are several vents or steam-holes, one of which acts as a sort preliminary vent or signal for the eruption of the geyser. The erup-ın of the Bee Hive is very fine and peculiar to itself, no other geyser the Basin acting in the same manner. It is preceded by a slight es-pe of steam, which is soon followed by a column of steam and water, ıich escapes in a steady stream, with great force, much as water is pro-ted from the nozzle of hose used with steam fire-engines. The column somewhat fan-shaped, and keeps a high average height. No water pears to fall, but the spray evaporates and is carried away as steam. ıere is probably but little water compared with the amount of steam, t there is a distinct water and steam period. The duration of the mer is from 2 to 5 minutes, as observed in 1878, and the latter only ew seconds. The force appears to be very great, and the ground is aken during the action of the geyser.

1870.—The Bee Hive was first seen in action in 1870, by the Washburn rty, by whom it was named. Lieutenant Doane describes it as follows:

> This morning we were awakened by a fearful, hissing sound, accompanied by the sh of falling water, and, looking out, saw on the other side of the stream a small ıter, 3 feet in height, and with an opening of 26 (?) inches in diameter, which had rcely been noticed on the previous day, and was now playing a perpendicular jet the height of 219 feet, with great clouds of steam escaping. * * * It played ıs steadily for 10 minutes, giving us time to obtain an accurate measurement by angulation, which resulted as above stated.*

Langford, in his description in Scribner's Monthly, gives the duration 18 minutes.†

1871.—The Bee Hive was not seen in operation by us nor by Colonel rlow's party.

1872.—The following are the observations I made in 1872:

Date.	Eruption began.	Eruption ended.	Length of eruption.	Interval.
	h. m.	*h. m. s.*	*m. s.*	*h. m.*
August 18, 1872	1 39 p. m.	1 44 00 p. m.	5 00	....
August 19, 1872	3 2 p. m.	3 17 00 p. m.	15 00	25 18
August 20, 1872	12 34 p. m.	12 38 30 p. m.	4 30	21 17

1873 and 1874.—I find no record of any observations on the Bee ive in these years. Edwin J. Stanley, in his "Rambles in Wonder-

*Report of Yellowstone Expedition of 1870, p. 32.
†Scribner's, vol. ii, p. 125.

land," p. 102, mentions an eruption lasting 15 minutes, but gives no pa ticulars of special interest.

1875.—Grinnell and Dana note three eruptions in 1875, as follows:

During a period of 60 hours there were three eruptions, the interval between th first and second being 26 hours, and that between the second and third 25 hours. Th duration of the action was 4 or 5 minutes, and the measured height 200 feet.*

1877.—General Sherman's party saw the Bee Hive in action twic and according to Colonel Poe it has an interval of about 14 hours.

1878.—On the 26th and 27th of August, before my arrival, the Be Hive was seen in action, and the eruptions noted by Mr. Richardso The following table shows the eruptions noted by us during our stay i the Upper Basin:

Table of eruptions of Bee Hive Geyser in 1878.

No.	Date.	Eruption began.	Eruption ceased.	Interval between the beginnings of eruptions.	Duration of water eruptions.	Duration of steam eruptions.	Maximum height.
		h. m. s.	*h. m. s.*	*h. m. s.*	*m. s.*	*m. s.*	*Feet.*
1	Aug. 26	2 07 00 a. m.	.....	.....	.....	.....	.....
2	Aug. 26	4 20 00 p. m.	.....	14 13 00	.....	.....	.....
3	Aug. 27	8 37 00 a. m.	.....	16 17 00	.....	.....	.....
4	Aug. 27	4 20 20 p. m.	4 25 00 p. m.	7 43 20	4 40	0 15	1
5	Aug. 28	8 36 05 a. m.	8 39 30 a. m.	16 15 45	3 25	.....	2
6	Aug. 30	11 33 25 a. m.	.....	.....	.....	.....	.....
7	Aug. 31	2 36 00 p. m.	2 40 45 p. m.	.....	4 45	.....	1
8	Sept. 10	2 36 10 p. m.	2 39 30 p. m.	.....	3 20	0 30	.....

NOTES.—Eruptions Nos. 1–3 were observed by Mr. Richardson.
Eruption No. 7 was observed by Mr. Ladd.
In No. 4 steam was still escaping *gently* 11 minutes after the eruption.
In No. 8 steam escaped gently after the steam eruption, and ceased 12 minutes after the end of th water period.

In the table I have given the intervals only between the eruptions tha were known to be consecutive. On the 28th and 29th I was in full sigh of the Bee Hive, and could not have missed seeing it in action had i played during the day-time. It is probable that eruptions occurred a night. If the 16-hour interval was observed, the next eruption afte No. 5 should have occurred at or about midnight of the 28th, whic might have been the case, as we were at that time asleep and had be come so accustomed to the noise of the geysers that they did not awake us when in action. If a 14-hour interval occurred followed by a 9-hou period and a 16-hour interval after it, the non-occurrence of an eruptio by daylight until the morning of the 30th would be accounted for. Th period of this geyser cannot be determined until observations are carrie consecutively through several days and nights. It appears that the in tervals obtained by myself in 1872, and Dana and Grinnell in 1875 (2 to 26 hours), were probably not the intervals between consecutive erup tions. The duration appears, from a consideration of all the observation that have been made, to vary from about 3 minutes to 18 minutes, thoug occupying oftener from 4 to 5 minutes. The heights measured are no quite as high as those noted by previous observers. The temperature taken were as follows: 4 p. m., on September 1, 5 feet below the top of th cone, 200° F.; 4 p. m., on September 1, 15 feet below the top of the cone 204° F.

*Report of Reconnaissance from Carroll, Mont., to Yellowstone National Park, &c. p. 131.

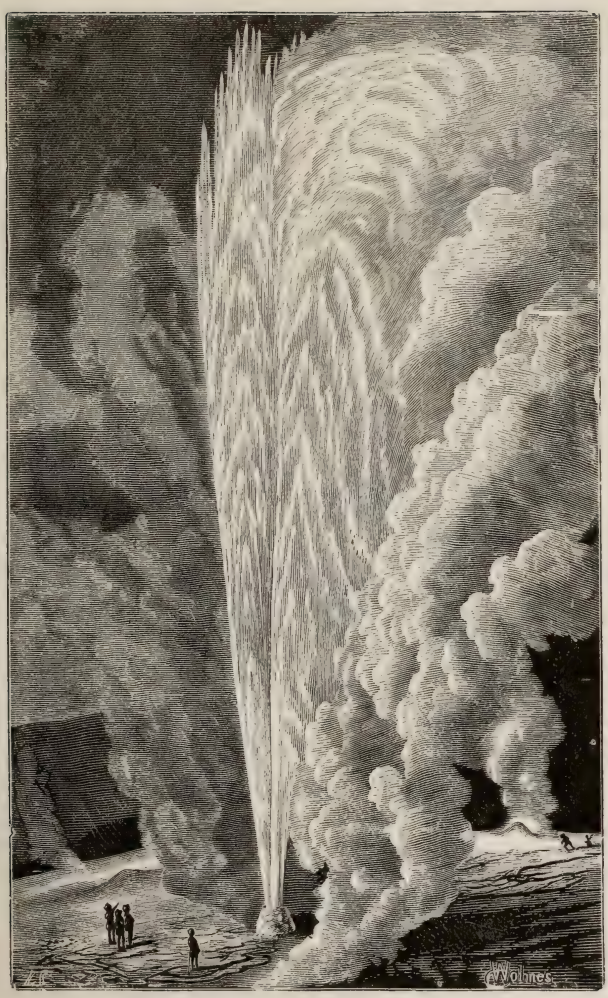

FIG. 11.—Bee Hive Geyser in action, 1872.

*Table showing comparison of observations on the Bee Hive Geyser.**

Year.	Observer.	No. of eruptions observed.	Interval.	Duration.	Maximum height of column.
1870	Doane			10 minutes	219*
1870	Langford			18 minutes	219*
1871†					
1872	Peale	‡3	21 to 25 hours	4½ to 15 minutes	
1873	E. J. Stanley	1		15 minutes	
1874†					
1875	Grinnell and Dana	3	25 to 26 hours	4 or 5 minutes	200*
1876†					
1877	Sherman and Poe	2	14 hours		
1878	Peale	§8	7 to 16 hours	3 to 5 minutes	205*
1879	Seguin			5 minutes	230
1881	Norris	3	16 to 30 hours	5 minutes	200

*These are measured.
†Not seen in action.
‡These are not known to be consecutive.
§Only five of these are consecutive.

1879.—Dr. S. Weir Mitchell saw two eruptions of the Bee Hive, but gives no interval nor duration. He thought it the "most perfect water-jet that could be imagined."

Trinity Geysers.—This name Professor Comstock has given to three bowls on a mound near the north end of the group.† To one of the three we have given the name Niobe Geyser, which is the only one seen in action by us. As there are four springs altogether, I have given the name Trinity to the three that are nearest together, and the name Niobe Geyser to the largest cone. In 1871 they were called the chimneys by Colonel Barlow;‡ but as Professor Comstock was the first one to record any eruption, I have given the preference to his name. The mound on which they are situated is the one on which in 1872 I found mice that had been scalded to death from which fact I judged the cones to be geysers (p. 149 of my report for 1872).

The mound is rather triangular in shape, measuring 42, 69, and 73 feet on the sides, and the summit is 43 feet above the level of the river. Its steepest side has an abrupt elevation of 20 feet. The three openings are on the west side on the broadest portion, while the Niobe Geyser is to the eastward somewhat isolated. In the illustration, Fig. 2, Plate XXIII, two of the cones of the Trinity are seen in the foreground, and the Niobe Geyser in the background.

* The following table is given in Professor Norris's report for 1881, page 57:

Bee Hive.

Date.	Time of eruption.	Duration.	Height.	Remarks.
		Min.	*Feet.*	
Oct. 4	9.45 p. m	5	175	Column of water always vertical, and of great symmetry and beauty
Oct. 5	2.15 p. m	5	200	
Oct. 6	8.40 p. m	5	180	

†Reconnaissance of Northwestern Wyoming, by Capt. W. A. Jones, in 1873, p. 254.
‡Reconnaissance of the Yellowstone River, 1871, p. 29.

a is a cone or mound from a foot to 18 inches in height, with an ori measuring 8 by 10 inches. The basin is yellow-lined and about 6 inc deep. The cone is covered with pearly beads of geyserite. When exa ined it was quiet, and had a temperature of 163° F.

b is an oblong mound 4 by 11 feet, with greenish tinted water, wh bubbles constantly on the sides and at the western end with period increased violence. At this end its mound or crater is 2 feet above general level, while at the opposite end it is only about a foot in heig The average depth of the basin is about 7 feet, except at the dee western end. There is considerable overflow from this basin. The is pointed and scalloped, lined with yellow, and projects slightly o the basin. The following temperatures were taken:

Surface	
5 feet below the surface	
8 feet below the surface	
10 feet below the surface	
12 feet below the surface	

c. This is the most important mound. It is oblong, with a circum ence of 25 feet at the base, and measures 5 by 5 feet on top. It h cone at one end with a height of 2½ feet, and at the opposite end little less than 2 feet above the general level. It is a white beaded m of geyserite, in which the orifice is a yellow-lined beaded diamond-sha opening, in which the water was spouting and sputtering all the t during our examination. At intervals the water spurted to a foot or above the top of the cone. The following temperatures were tak Surface, 180° F.; 6 feet below the surface, during boiling period, 203 The action in this cone appeared to be entirely independent of that i

The following are Professor Comstock's notes made in 1873:

> Another geyser (*c*), very near, spouted at 6.33 p. m., ceasing wholly at 6.35. had a similar orifice and chimney, not quite as high as the preceding, but the col of water was of nearly the same dimensions. A third geyser (*b*), with little o raised walls, but with a fair-sized pool, but a few feet from the others, spurted at for a few minutes, throwing the liquid about 60 feet into the air.*

These, which are the only observations of the height that are recor prove the Trinity Geysers to be of considerable importance. The ac was synchronous with the action of the Niobe Geyser, which was not case when we saw the latter in action in 1878.

Niobe Geyser.—This geyser, as I have already indicated, is inclu with the Trinity Geysers by Professor Comstock. It is an irregular, topped cone, 4 feet in height, having a circumference of 46 feet at base, and measures 5 feet in diameter on top. The orifice is 18 inc by 2½ feet. The outside of the crater is covered with white beaded g serite, and the throat of the orifice is lined with yellow, pearly-top bead-like masses. It is situated on the same platform with the Tri Geysers, from which it is separated by a slight depression. The tance between them is about 50 feet. Whenever seen the water in Niobe Geyser was in constant ebullition, spurting occasionally ab the top of the cone. The water appeared to bulge from one side. depth of the basin is about 5 feet. The following temperatures obtained: Surface, 199° F.; 4 feet below the surface, 199° F.

Professor Comstock saw it in action in 1873. He says:

> We had left the vicinity of the Grand Geyser late in the afternoon of August 25, were hastening to our camp at the upper end of the basin, when we were startle the eruption of another geyser at the edge of a broad terrace just above us. began at 6.30 p. m., continuing till 6.35.5 p. m. The water proceeded from a m

* Reconnaissance of Northwestern Wyoming, by Capt. W. A. Jones, in 1873, p

ised some 3 feet above the terrace, having a diameter of 5 or 6 feet. The water ached a height of 75 feet or thereabout.*

We saw but one eruption, which occurred at 8.14 p. m., August 27, 378. We were on the opposite side of the river at the time, near Old aithful, which spouted near this time, and no observations as to time r height were made. The column was, however, fully as high as the ne noted by Comstock (75 feet). With the few data it is of course. npossible to determine either the duration or interval of this geyser he remaining springs of the group are sufficiently described in the able.

THREE-CRATER GROUP.

This group is located almost due south of the Castle Geyser, from hich it is distant 1,200 feet. It is about 1,800 feet from Old Faithl, a little south of east from it. It is not in view from either, being rrounded by trees. It is named from the principal spring or geyser f the collection, and might well be called the mud group, for it conains about all the mud and turbid springs of the upper basin. It is lso one of the few places in which sulphur is seen in the upper basin. t is present, however, in very small quantity.

Although the table contains the temperatures of 37 springs, as the ap shows, they are but a small part of the whole number. Many of he turbid springs could not be approached on account of the soft ature of the surrounding soil, and but few of the mud springs have heir temperatures given.

*Reconnaissance of Northwestern Wyoming, by Capt. W. A. Jones, in 1873, p. 254.

Table of the Three-Crater Group.

Number and name.	Size and depth of spring.	Surface temperature.	Deep temperatures.	Time of observation.	Temperature of air.	Remarks.
		° *F.*	° *F.*		° *F.*	
1. Three-Crater spring and geyser.	A has orifice of 2 by 3½ feet. Depth, 5½ feet in center.	191	4 feet below surface, 195	12 m	72	White-lined basin with scalloped edge.
	B 21 by 26 feet, 10 to 11 feet deep.	187	9 feet below surfaee, 187			Main outlets are from *b*.
	C about 39 feet diameter, 4 to 8 inches in depth.	149 in pool				
	a is 15 feet by 20, and 12 feet deep.	*a* 162				
	b 5 feet deep	*b* 146				
	c is small hole.	*c* 151				
	D 9½ by 14 feet, with fissure 2 by 5½ feet.	*d* 156 to 179				*d* is the geyser. For complete notes see the text.
		145				This is at one end of C, into which its outlet leads.
2	12 by 15 feet, 16 feet deep	192	14 feet below the surface, 194			Gray basin, with triangular orifice. It had no outlet.
3	29 by 30 feet, 8 feet deep	*a* 156	*a* 2½ feet below the surface, 163.			White crater without outlet. Steam escapes from *a*. There are several small springs 6 inches to a foot near by.
	Two orifices; *a* 5 feet deep, *b* 8 feet deep.	*b* 156	*b* 7 feet below the surface, 165.			
	c 2 feet diemeter	*c* 180				
4	8½ by 9 feet; basin 1½ feet deep; fissure is 4 feet deep.	172	3 feet below the surface, 182			Dull bluish-gray basin.
4½	7 by 8 feet, 8 feet deep	184	7 feet below the surface, 195	2.20 p. m	71½	Brown crater spring with gray center.
5	5½ by 7 feet; pool 7½ feet deep.	In boiling center, 199	6 feet below surface in pool, 193.			Boiling spring.
5*a*	5 by 7 feet, 6 feet deep	181				Water is 3 feet below the surface.
6	17 by 18 feet, 12 feet deep	169	11 feet below the surface, 171.			These are connected, and outflow from 6 passes over 6 *a*, when it is joined by overflow of No. 7.
6*a*	Basin 1 to 2 feet deep, with hole.	185				
7	5 feet diameter, 13 feet deep.	171	11 feet below the surface, 183.			
8	6 by 6½ feet, 5 deep	158				Yellow-white funnel-shaped pool about 45 feet from No. 6.
9	10 by 12 feet, 6 feet deep	185	5 feet below the surface, 186	2.30 p. m	71½	Gray basin.
10	8½ by 11 feet, 2 to 3 feet deep.	195				Hot milky-white boiling tub.
11	11 by 25 feet					Pool receiving water from No. 6.

MAP
OF THE
UPPER GEYSER BASIN
YELLOWSTONE NATIONAL PARK

13	8 by 13½ feet, 2 feet deep	196	1 foot below the surface, 197			Water is 2 or 3 feet below the surface.
14	*a* 7½ by 7 feet	*a* 186				
	b 8 by 8 feet	*b* 191				
15						Spouting holes.
16	Irregular basin, 36 by 19 or 20 feet and pool.	*a* 147				Irregular yellowish-green basin, with pools at one end.
	a above end	*b* 142				
	Depth 4½ to 5 feet	*c* 135½				
		a 141				
17	3 feet 9 inches by 5 feet 3 inches.	175				Black and brown shallow basin.
18	8 by 9 feet					Red-lined dead pool.
19	Collection of mud-pots in space 28 by 47 feet. The pots are from 2 to 4 feet diameter.	Not taken				Light colored mud.
20	Collection of mud pots					Red and pink mud, very thick and steaming.
21	Mud pots and steam-vents	Not taken				
22	Area riddled with holes; space occupies 108½ by 75 feet.	....do				Water from No. 9 flows into this space.
23		*a* 195				Deep holes of turbid water.
		b 192				
24	21 by 7, 8, and 13 feet	Not taken				The water is red, and beautiful formations line the cone-like spring.
26	4 by 6½ feet, 12 feet deep		10 feet below top, 174			Gray bottomed pool, with hard border.
27	*a* 1 foot 4 inches by 1 foot 2 inches.	*a* 166				Three craters close to each other.
	b 2 feet by 1 foot 10 inches.	*b* 195				
	c 1½ by 2 feet	*c* 180				
28						Collection of dead and dying mudholes and water pools.
29	32 by 9 feet					Mud puff and pool.
30	23 by 18 feet					Turbid green pool.
31						Large, muddy pool.
32	10 by 10 feet	174			40	Gray pool.

DESCRIPTION.

No. 1. *Three-Crater Spring and Geyser* (Plate XXIV).—This spring derives its name from the fact that there are three basins connected by narrow passages.

A is the basin at the south end in the foreground of illustration, and is about 12 feet in diameter, having a depth of 5½ feet, at the bottom of which the orifice is about 2 by 3 feet. It is a white basin with an overhanging raised scalloped edge of grayish-white geyserite. Outside of this the tints are light salmon and salmon-gray. The water has a light bluish tint and bubbles gently at intervals. There appears to be some overflow to the central basin. The surface temperature was 191° F. At 4 feet below the surface it was 195° F. This basin is the one in the foreground of the illustration. There are two or three outlets when the basin is full.

B.—This is the central basin, and appears to receive water from both the others, for which it acts as a reservoir. The main overflow is from this basin towards the east. It is almost circular, measuring 21 by 26 feet. It is a quiet pool, with a white basin, over the center of which the water has a greenish-blue tint, and a temperature of 187° F., both at the surface and 9 feet below it. The outer edges of the basin are composed of laminated and flaky geyserite, inside of which the sides slope into a basin 10 or 11 feet deep. The rim of the basin is grayish white capped with light yellow.

C.—This is the northern and largest basin of the three. It might be considered as two, *a* being similar to B; but there is no narrow passage between it and the larger portion of the basin in which *b*, *c*, and *d* are situated. It merely expands beyond *a*. On the west side it is about a foot high with small basins outside. In this direction there is evidently considerable overflow at times. The bottom of the basin is flat until the openings are approached, and is of a creamy white color and light saffron, except over the orifices, where it is of a bluish tint. The edge is gray and white with yellow and pink tints on the west. It overhangs on the north side. At this end also the basin is lined with flakes of geyserite. The depth is from 4 to 8 inches, and the temperature 149° F. in the center, *a*. The main basin about *a* is 29 feet wide. *a* itself is 15 by 20 feet and 12 feet deep. It is a quiet blue-tinted hole with two holes in the bottom. Its surface temperature is 162° F.

b is towards the west side of the main basin, and is a hole about feet deep, over which the water has a deep greenish tint. Around the basin is light yellowish white. The temperature is 146° F.

c is a small hole with mottled yellow and white lining and a temperature of 151° F. It is near *b*, on the west side of the main basin.

d. Three-Crater Geyser. This is towards the east side of the main basin which here slopes to an orifice of about 2 feet diameter, from which the steam escapes and causes the spouting. The steam appears to escape with great effort, and makes a startling noise that is more like the noise made by a pack of fire-crackers muffled in a box than anything else can think of. It raises the water in great bulges, splashing in all directions, with thumps. Every now and then a jet is squirted to a height of 15 or 20 feet, but the average is about 5 feet. The water in the main basin C and in B is thrown into waves, with beautiful effect, causing overflow from the latter. The steam does not appear to heat the wat

THREE CRATER SPRING AND GEYSER, UPPER FIRE HOLE BASIN

much. The following are the temperatures obtained on August 30, between 10 a. m. and 11 a. m.

	° F.
Surface temperature immediately before the eruption	159
Surface temperature during the eruption	169
Surface temperature immediately after the eruption	163
Surface temperature two minutes after the eruption	156
Temperature two feet below the surface three minutes after the eruption	179

The following are the eruptions that were noted:

No.	Eruption began.	Duration.	Interval of quiet.
	h. m. s.	*m. s.*	*m. s.*
1	10 52 5 a. m.	1 10	
2	10 56 55 a. m.	1 05	3 40
3	11 02 28 a. m.	57	4 28
4	11 07 45 a. m.	45	4 20
5	11 12 30 a. m.	1 10	4 26
6	11 17 30 a. m.	1 00	3 50
7	11 22 25 a. m.	1 00	3 55
8	11 27 15 a. m.	1 00	3 50
9	11 32 00 a. m.	1 02	3 45
10	11 36 59 a. m.	1 06	3 57
11	11 41 51 a. m.	59	3 46
12	11 46 36 a. m.	1 01	3 46
13	11 51 22 a. m.	1 03	3 45
	Averages	1 $01\frac{5}{13}$	3 $57\frac{1}{13}$

From the limited time devoted to the examination of this geyser it is impossible to determine whether these are distinct eruptions or only periods of an action that is separated by longer periods of quiescence.

D.—This is a basin $9\frac{1}{2}$ by 14 feet at the north end of C, into which it discharges water through a channel $2\frac{1}{2}$ feet wide. In this basin is a fissure 2 feet by $5\frac{1}{2}$ feet. The basin is yellowish-red and the fissure mottled with lighter colors and greenish at the bottom; the temperature is 145° F.

The spring I have just described is northwest of the main group, and is separated from the rest of the springs by trees. A large area of white and gray deposit, on which dead trees are standing, slopes toward Iron Spring Creek and to the northward from the spring. There is a low-timbered hill between it and the Castle.

A temperature taken in basin C in 1871 was 178° F., but its character as a geyser was not noted that year. Its name was given in 1872 by Mr. Bechler.

Nos. 6 and 6*a*.—These are two springs in one basin; No. 6 is the main bowl, although 6*a* is the more active spring. No. 6 is a white funnel-shaped basin, with greenish-blue tinted water. The basin is shallow around the spring in 6*a*, being from a foot to 2 feet in depth. The overflow from No. 7 flows into 6*a*. The entire length of 6 and 6*a* is about 49 feet; 6*a* is 24 feet wide in widest portion, near where the overflow of No. 7 comes in.

No. 10. This is a boiling, white, muddy spring. The water is milky-white in color, and boils in one corner from under a rock, although there are several points of slight bubbling. The water is four feet below the general level, and has a temperature of 195° F. In 1872 I obtained a temperature of 196° F. in this spring.

No. 16 is an unimportant pool of irregular shape. The bottom is divided into several basins by ridge-like divisions.

No. 19. In this collection there are about a dozen pots of light-colored mud.

No. 24. This is a red mud spring in a cave-like hole 6½ feet below the general level. The hole is 21 feet by 8 to 13 feet, but the spring is only 5 by 7½ feet. The water is a thin red mud, which bubbles and splashes against the walls, forming red stalagmitic processes, which are very pretty. In the hole with the spring is a steam hole, at the wider end, surrounded with moss.

No. 30 is a large, green turbid pool surrounded by numerous mud pots and slimy holes of muddy water. These extend through the space intervening between Nos. 30 and 31.

A number of the springs in the group are boiling and bubbling (Nos. 5, 12, 13, 15, 25, and 27), but there are none so far as known that deserve the name of geyser except No. 1. There are many steam vents not enumerated in the table, and some of the more quiet springs may have periods of increased activity. Our time was short and occupied mainly in mapping the springs, so that we cannot distinguish all the springs that are periodic in their action.

The table gives the points noted in relation to the springs that have not had special mention here.

EMERALD GROUP.

This group is situated mainly at the forks of Iron Spring Creek, 1,600 yards west of the Castle Geyser and 1,000 yards southwest of the White Pyramid. It is separated from the main groups by a considerable growth of timber, mainly pines.

On the right-hand branch, 800 feet above the main springs of the group, is a wide marsh, in which there are a number of warm-water pools and several springs. Of the latter three were examined, and the following are the results:

a. Small white mound, 1 by 2½ feet, with a hard, geyserite edge, in which the water was a foot below the surface and had a temperature of 187° F.

b. A greenish-yellow lined basin, measuring 7 by 8 feet, in which the water had a temperature of 160° F.

c. An irregular shaped basin, 20 by 30 feet, in the marsh. As a spring it is nearly extinct, and the temperature was not taken. The marsh had an abundant deposit of ferric oxide.

I have also included the Black Sand Geyser (or spring, for its title to the name of geyser is not settled) in this group, although it is separated from the other springs by trees. It does not come in very well with any other group, however, and this appears to be the best place to consider it.

The Emerald Group is so far from the location of the principal geysers that very little time is usually devoted to it in comparison with the other groups. Of the 15 springs enumerated in the table, no one has been observed to be a first-class geyser. Nos. 1, 2, and 15 are the only ones that afford indications of geyseric action. The group is well worth a visit, however, as the Emerald Spring is remarkable for its beauty, and the Great Hot Basin for its great size, almost rivaling in this particular the large spring of the Egeria Group in the Lower Basin. It is not, however, so remarkable for the brilliancy of its coloring as the latter.

EMERALD GROUP RIGHT BANK OF IRON SPRING CREEK UPPER FIRE HOLE BASIN

Table of the Emerald Group.

Number and name.	Size and depth of spring.	Surface and other temperatures.	Time of observation.	Temperature of air.	Remarks.
1	Cone, with orifice 18 by 12 inches at bottom of basin, of 6½ by 7 feet.	.....	.....	....	No water in the basin when visited.
2. Great Spouter	20 by 25 feet	198	.....	....	Great escape of steam.
3. Green Spring	50 feet diameter, 25 feet deep.	195	.....	....	Known as Emerald Spring on map of 1872; water is bluish-green rather than emerald color.
4	43 by 10 to 15 feet, 6 or 7 feet deep.	183	.....	....	Oblong with scalloped edges.
5	4 by 2½ feet is average size.	*a* 192	.....	....	*a* milky.
		b 155	.....	....	*b* clear.
		c 186	.....	....	*c* milky.
		d 186	.....	....	*d* clear.
6	3 by 6 feet	187	.....	....	In hard geyserite.
7	2 by 3 feet	...	.....	....	
8. Great Hot Basin	140 by 200 feet; could not get depth.	*188	.....	....	Has yellow, white, and grayish basin and 6 or 7 centers or spring holes; bulges in one of the central ones, throwing water into waves. The overflow goes in two directions over brilliantly colored terraces.
9	60 by 8 feet	173	.....	....	Crater-like greenish-tinted basin.
10	6. feet diameter, 3 feet deep in center.	170	.....	....	Yellow and red margin, with red outlet and white basin.
11. Emerald Spring	36 feet long and 28 to 42 feet wide, 35 feet deep.	148	.....	....	Known on map of 1872 as the Great Emerald Spring. It is beautiful emerald tint with yellow-green basin and ornamented edge. Outlets are brilliantly colored with deposit of iron.
12	3½ by 5 feet	(†)	.....	....	Water is 4 feet below the surface. It is a crater-like hole, with red and yellow lining.
13	3 by 1 foot to 18 inches..	197	.....	....	Yellow-lined hole in the geyserite on the river bank.
14	18 by 23 feet	189	.....	....	On the river's edge, above which it rises 2 to 3 feet, with a corrugated basin and bulging center.
15. Black Sand Geyser.	55 by 60 feet	194	.....	....	

*At north end. †Can't be taken.

DESCRIPTION.

No. 1.—This conical mound of hard gray geyserite is about 8 feet high, and on the summit has a yellow-lined funnel-shaped basin, 6½ by 7 feet, in which the orifice is about 12 by 18 inches. The basin was empty when we saw it this year, but the water could be heard boiling far below in the tube, and there is no doubt that it has periods of spouting, although the column may not be projected to a great height. A temperature taken here in 1871 was 152° F.

No. 2. *Great Spouter.*—In this basin the water was in violent ebullition, spurting and spouting constantly with a great escape of steam. The water-way leading from it to No. 4 is brilliantly colored with yellows, orange, and reds, the latter predominating as the river is approached; greenish prevailing near the spring.

No. 3. *Green Spring.*—This spring, on the map of 1872 and in Plate XXVII, is called Emerald Spring, but the tint is bluer than an emerald color, so I have called it simply Green Spring, especially as there is an Emerald Spring on the opposite side of the creek. This basin is somewhat heart-shaped, and consists of a deep cavern-like pool and a smaller shallow gray pool near the outlet. The temperature was 195° F. A temperarure taken here in 1871 was only 170° F.

No. 4.—This is a very handsome oblong pool of greenish-tinted water, with an overhanging white scalloped rim. There is a boiling center at the back of the spring. This is the spring shown in Plate XXV.

Nos. 5, 6, and 7 are unimportant springs, sufficiently described in the table.

No. 8. *Great Hot Basin.*—The water from this bulging basin flows over brilliant red terraces. The basin is generally flat, except in the center. The temperature (188° F.) was taken at the north edge. In the background of Plate XXVII, near the trees at the right, the steam from this spring is seen rising.

No. 9.—In this spring there are two basins, only one of which contained water when examined. At times, however, the water fills both, making one spring.

No. 11. *Emerald Spring.*—It is somewhat irregularly rectangular in shape. In the center is a rhomboidal-shaped pit or bowl 35 feet in depth, over which the water is of a deep emerald green color, becoming yellowish green towards the edges. Outside of this central bowl is a shallow basin reaching to the edge of the spring, which is bordered by a red and brown line. This shallow portion is light yellow in color. The tint over the central bowl is so deep that the bottom cannot be seen. The water-ways which carry off the overflow are brilliantly red on a brown and grayish white ground. The deposit covers a considerable area, and scattered over it are a number of dead standing trees.

Nos. 12 and 13 are not indicated on the map. They are on the creek bank.

No. 14 (Plate XXVI) is on the bank of the creek at a bend, and its basin rises from the water's edge. The water has an inky tinge over one orifice, and at the other the basin is grayish white. The border is corrugated, with a gray edge and yellow beaded silica on it. The main orifice bulges at short intervals.

No. 15. *Black Sand Geyser* (Plate XXVIII).—This is one of the most beautiful springs in the Upper Basin. It has a delicate rim, with toadstool-like masses around it. The basin slopes rather gently towards a central aperture that to the eye appears to have no bottom. The water in the spring has a delicate turquoise tint, and as the breeze sweeps across the surface, removing the steam, the effect of the rippling of the water is very beautiful. The sloping sides are covered with a light brown crust; sometimes it is a rather dark cream color. The funnel is about 40 feet in diameter. The entire space covered by the water is about 55 feet by 60 feet. Outside the rim of the spring is a border of pitchstone (obsidian) sand or gravel sloping 25 feet.

From the west side flows a considerable stream, which forms a most beautiful channel, in which the colors show a remarkable variety of shades. The extremely delicate pinks are mingled with the equally delicate saffron yellows, with here and there shades of green. These colors are from deep yellow to pale creamy salmon. The stream or outlet runs down nearly to the base of the trachyte wall on the west side of the basin, spreading out over a large area, which is covered with its deposits. (See Plate XXIX.) The main channel, which carries off the largest

EMERALD GROUP LEFT BANK OF IRON SPRING CREEK UPPER FIRE HOLE BASIN

EMERALD SPRING UPPER FIRE HOLE BASIN

proportion of the overflow, is underlaid with the most delicate salmon-colored silica. There is also a great amount of the soft gelatinous matter, which is probably the new variety (*viandite*) described in another portion of the report.

IRON-SPRING GROUP.

Under this name I have included a number of springs on the west side of Iron-Spring Creek, mostly some distance above the level of the valley at the foot of the bluffs. Some of them are from 125 to 150 feet above the level of the creek. These springs have never been carefully examined, as they are small and comparatively unimportant. They are characterized by a deposit of ferric oxide.

With these may be included a group of springs on the Little Fire Hole River, about a half mile above its mouth in the cañon. They are just beyond the limits of the map, and are referred to by Professor Bradley (report for 1872, p. 241) as "small hot springs." I have mentioned these springs in order to make the reference to the springs as complete as possible.

RECAPITULATION OF UPPER GEYSER BASIN.

The following is a recapitulation of the springs and geysers of the Upper Geyser Basin:

Name.	Number of springs.	Highest temperature.
		° F.
Soda Geyser Group	33	194
River Group	11	190
Cascade Group	14	192
Grotto Group	33	198
Giant Group	9	197
Round Spring Group	9	196
White Pyramid Group	35	200
Castle Group	38	198
Grand Group	80	199
Old Faithful Group	5	200
Upper Springs	22	.....
Giantess Group	61	199
Three Crater Group	45	199
Emerald Group	28	198
Iron Spring Group	17	.....
Total	440	.....

This gives not only those that are catalogued in the preceding pages, but all that are shown on the map, except in the case of the Three Crater Group, all of which are not given even on the map. All of the springs referred to are not given above, as some are beyond the limits of the map.

The following table gives a list of all the principal geysers in the Upper Basin, and their periods, heights, and durations as far as known:

Geysers of the Upper Geyser Basin.

Name of geyser.	Group in which situated.	Interval or period.	Duration of eruption.	Height of column.
				Feet.
Soda	Soda Geyser Group	About 10 minutes	.....	.....
Restless	River Group	.....	.....	.....
Sentinel	Cascade Group	.....	.....	20
Grotto	Grotto Group	Several times a day.	Half hour to 2½ hours	20 to 60
Fan	....do	.....	9 to 30 (?) minutes	About 60

Geysers of the Upper Geyser Basin—Continued.

Name of geyser.	Group in which situated.	Interval or period.	Duration of eruption.	Height of column.
				Feet.
Riverside	Grotto Group		10 to 13 minutes	About 80
Giant	Giant Group	A long unknown period.	1½ hours to 3 hours	130 to over 200
Young Faithful	do			10 to 30
Oblong	do	Once or twice daily.	6 minutes	
Spray	White Pyramid Group.			
Comet	do	13 to 22 minutes*	30 seconds to over a minute.	30
Punch Bowl	do	Not positively known as a geyser; spouts daily, but full period not known.	Water period 9 to 20 minutes; entire duration 1 to 1¾ hours.	50 to 200
Castle	Castle Group			
Castle, Jr	do			
Grand	Grand Group	16 to 31 hours	10 to 42 minutes	95 to 200
Saw Mill	do	About 5 eruptions daily; *i.e.* in 24 hours.	1¾ to 3 hours	15 to 20
Tardy	do			
Bulger	do			5
Turban	do	About 15 minutes	15 seconds to 5 minutes.	25
Spasmodic	do			5
Old Faithful	Old Faithful Group	50 to 70 minutes	3 to 5 minutes	75 to 150
Giantess	Giantess Group			250
Bee Hive	do	7 to 25 hours	3 to 18 minutes	200 to 219
Trinity†	do	Not known	About 3 minutes	60
Niobe	do	do	About 5 minutes	75
Three Crater	Three Crater Group	Interval of quiet average 3 minutes 57 seconds.	45 seconds to 1 minute 10 seconds.	15 to 20

* These are the periods between the constant eruptions and not between the great eruptions, the times of which were not observed.

† Only the larger of the Trinity geysers is noted here; a second one spurts but not quite so high.

CHAPTER IX.

THIRD GEYSER BASIN OF FIRE HOLE RIVER.

The Third Geyser Basin is a little over 2 miles above the falls that are a short distance above the Upper Geyser Basin. This basin was hastily passed through by us on our way from Shoshone Lake to the Upper Basin, and no time was afforded to examine it closely. I therefore quote Professor Bradley's description, which is the only one that has been published, the party with which he was connected as geologist being the one that discovered the basin:

These hills [above the falls] soon approach the river again, which has here a very narrow valley. This, however, suddenly widens again into a third geyser basin. The first intimation of hot springs, if we follow up the river bank, is a strong column of steam appearing among the timber on the east side of the valley, just as we enter the basin. Mr. Taggart visited this vent and reported a boiling pool, temperature 190°, overhung by rocky banks, which showed no signs of spouting. As we emerge from the timber on the west side we find the lower angle of the basin occupied by an area of hot springs, perhaps 500 feet long by 250 feet wide, with the usual floor of disintegrating, siliceous sinter, and containing numerous vents, mostly active. Near the center of this area stands the chimney of a single geyser. This is a dome-shaped mound, averaging 15 feet in diameter, and from 11 to 14 feet high, completely covered with most elegant varieties of the pearly beads before described. It is striped vertically with bands of white, dark green, brownish black, and various shades of yellow and orange, the white being ordinary geyserite, while the other colors are apparently of purely vegetable origin. On the north side of the dome, where the main flow from the eruption is now generally scattered, the geyserite has also a beautiful, delicate, pink tinge. The summit of the northwest side, as seen from the northeast, is ornamented

BLACK SAND SPRING UPPER FIRE HOLE BASIN

VIEW FROM THE BLACK SAND SPRING UPPER FIRE HOLE BASIN

with a fine profile of a mild-featured human face done in the bead-work. The top of the mound is perforated with numerous small three, four, and five angled apertures, and a single larger one between 2 and 3 inches in diameter. In eruption this larger opening throws a stream from 20 to 50, and even to 70 feet in height, mostly in drops with much steam. Though the amount of water ejected is small, yet the force is very great, and, in this respect, the eruptions much reminded us of those of the Castle Geyser. Its highest jets are generally about the midde of the period of eruption. Eruptions take place at somewhat irregular intervals, but generally are about two hours apart. During such as were carefully observed, there was first a period of violent activity, continuing from 3 to 4 minutes and ceasing suddenly; then a quiet interval of from 11 to 24 minutes; then a second active period of from 23 to 26 minutes, closing gradually with a rush of steam and occasional water-jets. The small vents spit furiously all through the eruption, their jets reaching 3 feet or more in height, when the main jet was at its culmination. About 10 yards off, on the platform, a small vent is in sympathy, but it is so nearly stopped as to be generally overlooked. I think it probable that this was wider in the younger days of the geyser, and has become stopped up equally with the latter. It is evident that eruption at this point must soon cease, unless the great force developed beneath shall be able to break away the upper part of the dome. It is more probable, however, from facts observed in the other basins, that a new vent will be opened and a new mound built. I could not obtain the temperature of the water of the geyser, since the water, except just before and during the eruption, retired below the surface-openings, and we had no self-registering thermometers with which to measure its heat from a safe distance. The surrounding springs, which are nearly all boiling, gave temperatures varying from 185° to 192°. The general elevation of the basin is about 7,770 feet, at which the theoretical boiling point is about 198°. The single geyser of the basin was called the Solitary.

This small basin spreads perhaps a half mile from the stream, and includes near its northwest corner another cluster of hot springs, some of which reach 186°, surrounded by variously colored deposits, including some sulphur. The trail of our main party entered the basin at this point. The central part of the basin shows the vents and deposits of numerous scattered springs, most of which are nearly or quite extinct, only a few of them still boiling.*

After a short interval of timber, another, small meadow-like basin opens to view, occupied by a few small warm springs of no importance.

The basin surrounding the head or the river is occupied by quite a large meadow, tolerably dry in the middle, where the stream winds along, but very swampy all around its border, where numerous cold springs escape from the hills. The sites of a few old hot springs, long since extinct, are marked by the patches of the much-disintegrated white geyserite, now mostly buried under the tall grasses and sedges which cover the meadow.†

It will be seen from the descriptions just quoted that the springs of the Third Geyser Basin are in a dying condition as compared with those of the Lower and Upper Basins.

SECTION III.—SPRINGS ON SNAKE RIVER DRAINAGE.

CHAPTER X.

SHOSHONE GEYSER BASIN.

The Shoshone Geyser Basin is located at the western end of the western arm of Shoshone Lake, and comprises an area of about a square mile. At present the active springs are scattered along both banks of Shoshone Creek for a distance of more than half a mile. Most of the springs are separated from the lake by low timbered hills.

History.—The Shoshone Geyser Basin was named by Professor Bradley in 1872,† from Shoshone Lake, although properly the lake should probably be known as De Lacy's Lake, but, as in the case of Yellowstone Lake, the name that has the right of priority has not been retained. We passed around a part of the lake in 1871, but supposed it was the head of the Madison, and it was so named on our map of that year.

*Report of U. S. Geol. Survey for 1872, 1873, pp. 241, 242. †*Ibid.*, p. 234.

Captain De Lacy, however, did not visit the geyser basin himself, as the following extract from his article in Contributions to the Historical Society of Montana (page 130) will show:

> They [*the party that left them*] passed Lake Lewis and came to the foot of the large lake, where they found our old camp. Here they went up on the west side of the lake to its head, and there found a number of hot springs, some of which were geysers, which they saw in action, spouting up the water to a great height, and thence went over to the South Fork of the Fire Hole River, where they again saw our camps, and thence down the Madison River to Virginia City. These facts I obtained afterward at Bannock City from Mr. Charles Ream, one of the party, and it was thus established conclusively that the large lake was the head of the South Snake, and I was enabled to correct the course of the Madison River, and correct my surveys with it.
>
> The lake which we had now discovered was the lake afterward called De Lacy's Lake on the United States surveyor-general's map of the Territory, and afterward renamed Shoshone Lake by Dr. Hayden, and the lake below it was the one called by him Lewis Lake.*

General Meredith, surveyor-general of Montana in 1867, named the lake De Lacy's Lake, and it was so called on several editions of a map issued by the Messrs. Colton, of New York.† Captain De Lacy is mistaken in thinking that Dr. Hayden renamed it, as Prof. F. H. Bradley did so, and gives as reasons for so doing the fact that the position on De Lacy's map does not correspond, and that there are numerous other errors.‡ No matter what name the lake may be known by hereafter, the Geyser Basin will be known as the Shoshone Basin, the name given by Professor Bradley, who was the first person to give anything like a detailed description of its springs and geysers. The principal geysers were named by him. The general elevation of this geyser basin is 7,825 feet, and the theoretical boiling point is between 198° F. and 199° F. The slopes of the plateau surrounding the lake are all very heavily timbered.

Geology.—The geology of the region of the Shoshone Geyser Basin is exactly like that of the Geyser Basin of Fire Hole River. Rhyolitic rocks form the main mass of the plateau, the summits being composed of black and brown obsidian. In various parts of the basin there are remnants of a sandstone, which seems to be composed of particles of obsidan and broken-up geyserite. In some places it appears vitrified, as though it had become permeated with the siliceous waters from the springs. The marsh below the springs has a number of steam vents and old springs. It is probable that this marsh is sometimes overflowed by the lake. Six or eight of the springs in the marsh are easily recognized, but were inaccessible at the time of our visit.

Shoshone Creek is a rapid stream, some 10 to 15 feet in width, which flows from north to south through the basin. The temperature of its water opposite the Yellow Crater Group was 70° F., and below the mouth of Fall Creek, below all the springs, it was 80° F.

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* On pages 142, 143, of the article from which this extract is taken, Captain De Lacy says: "I never claimed that my map was correct in all particulars, or that I had been entirely over the region in question. Outside of the surveys and my own explorations I was obliged to rely on the reports of others who had been there hunting or exploring, and these were not always accurate. I put down what I considered the best, hoping to be able to improve the map every year, and make it thoroughly correct finally. I do claim, however, that I was the first to publish the fact that the South Snake River took its rise in a large lake north of Lake Jackson and flowed into it—a fact confirmed by Dr. Hayden's own surveys—and this would authorize me, according to the general rules governing geographers, to name it myself, or for others to give it my name."

† Historical Society of Montana, Vol. I, page 141.

‡ Report U. S. Geol. Survey, 1872, page 244.

THE ORION GROUP.

The Orion Group of springs, named in 1872, was the first group examined by us. It is on the east side of Shoshone Creek, about 900 feet west of the lake shore. The springs are on a kind of plateau of geyserite which is from 25 to 30 feet above the level of the lake. The southern edge of this low plateau is fringed with pines; beyond this to the south are the meadows and marshes that border the creek before it flows into the lake. There are trees scattered over the plateau separating some of the springs from the others and concealing them.

The Union Geyser is the principal geyser in the Shoshone Basin and is in this group. The deposit about the geyser is soft and easily broken through, but in other places on the plateau it is generally hard and firm enough to make good walking. The springs of the group are mostly quiet springs, although several, as the catalogue will show, are good boiling springs; none except the Union is known to spout more than a foot or two.

The springs besides the Union Geyser deserving mention are the Taurus, Marble Cliff, Impenetrable, and the Kitchen Springs.

Table of the Orion Group.

Number.	Name.	Size of spring.	Surface temperature.	Deep temperatures.	Temperature of air.	Time of observation.	Remarks.
			° F.	° F.	° F.		
	Taurus	6 by 7 feet	196	3 feet below surface, 197; 6 feet below surface, 202; 8½ feet below surface, 204.	55	Aug. 16, 1878	Named in 1872 by G. R. Bechler.
1	Impenetrable	10 by 14 feet, 19½ feet deep	199	5 feet below surface, 196; 7 feet below surface, 195 at north end.	63	Aug. 17, 1878, 2.45 p. m.	Named by Bechler in 1872. On the north side the water is 2½ feet below the rim; on the west side the rim is 8½ feet high; on the east 5 feet, and on the south 8 feet. The spring is depressed.
2		Hole 4 feet deep	197		63	Aug. 17, 2.30 p. m.	This spring is nearly extinct and has a very small opening.
3		26 by 26 feet; 17 feet deep in the center; opening to tube 3 by 2 feet; basin shallow, 6 inches deep.	*154 †153		64	Aug. 17, 3.10 p. m.	Large pool, almost heart-shaped, with yellow lining.
3½			180 to 192		64	Aug. 17, 3.10 p. m.	Three or four sputter holes back of No. 3.
4		9 by 14 feet; pool is 6 inches deep.	†164 ‡175		64	Aug. 17, 3.11 p. m.	Gray pool, with a deeper orifice at east end. This center is in ebullition.
4½			144			Aug. 17, 3.10 p. m.	Small dead spring between 2 and 4.
5*a*		5 by 7 feet, 3 feet 10 inches deep.	145	2½ feet down, 180	64	Aug. 17, 3.20 p. m.	White, crater-shaped spring; old vent at one end.
5*b*		5 feet 9 inches deep	181	4½ feet, 181	64	Aug. 17, 3.20 p. m.	Water is 6 inches lower than in 5*a*.
6		8 by 8 feet, 5 to 30 inches deep	186	1 foot 4 inches below surface, 195; 8 feet below the surface, 200.	64	Aug. 17, 3. 25 p. m.	The water is milky-white and has a scum on the surface.
7		2 by 2½ feet, 2 feet deep	187		62	Aug. 18, 1.40 p, m.	
8	Moss Crater	6 by 7 feet, 4 feet deep	195	4 feet below the surface, 165	64	Aug. 18, 1.45 p. m.	
9		18 inches in depth	105		62	Aug. 18, 1.40 p. m.	Small, dead pool.
10		17 by 18 feet; circular crater; water is 8 feet deep.	134		64	Aug. 18, 1.50 p. m.	Large circular crater, in which the water is 5 or 6 feet below top. The spring is nearly dead, bubbling a little at intervals of a few minutes. The rim is of laminated geyserite and the spring is lined with greenish-brown confervoidea.
11	Marble Cliff Spring	23 by 11 feet, 15 to 16 feet in depth	153	8 feet below the surface, 166.	64	Aug. 17, 1878, 1.55 p. m.	The water in this spring is perfectly quiet and deep blue in color.

*In center. †In the pool. ‡In the spring.

12		15 by 18 feet; shallow pool, only 5 or 6 inches deep.	124		64	Aug. 18, 2.15 p. m.	
13		7 by 13 feet; pool is a few inches deep.	163	2 feet below surface, 184	64	Aug. 18, 2.15 p. m.	The pool has a small, irregular opening at one end; basin lined with geyserite.
14		Space of 13 by 3 feet, with a number of holes.		3½ feet below the surface in *a* the temperature is 199.	61	Aug. 18, 2.45 p. m.	In the main spring there are four centers of ebullition (*a*, *b*, *c*, *d*). Altogether there are about 11. The edges of *h* and *i* are sulphur-lined.
		a 5 feet in depth	*a* 196				
		b 2 feet in depth	*b* 192				
		c 1 foot in depth	*c* 171				
		d 1 foot in depth	*d* 158				
		e 5 feet in depth	*e* 167				
		f 6 inches in depth	*f* 190				
		g 6 inches in depth	*g* 189				
		h 3 inches in depth	*h* 172				
		i 2 inches in depth	*i* 170				
15		2 feet in diameter, 2 feet deep	160		61	Aug. 18, 2.50 p. m.	This is a quiet pool lined with geyserite fragments. The opening at bottom of spring is 1 foot by 5 inches.
16		3 by 3 feet, 4 inches deep	84		61	Aug. 18, 2.50 p. m.	Quiet, red pool, with scum on the surface; it is evidently a dead spring.
17		Entire length from *a* to *c* 4 feet	*a* 150 *b* 170 *c* 110		60	Aug. 18, 2.55 p. m.	These vents are sulphur-lined and are near No. 14.
18		Basin measures 14 by 13 feet; orifice is 8 by 3; 25 feet 5 inches in depth.	152	8 feet below the surface, 155.	60	Aug. 18, 12.20 p. m.	Quiet spring, with broad, yellowish basin, in which the water is yellowish-green tinted.
19		2 by 3 feet; 4 feet 10 inches in depth.	188	3 feet below the surface, 188.	62	Aug. 18, 12.45 p. m.	This is a white-bordered spring, lined with red gelatinous material.
20		Basin is 24 feet in diameter; spring 13 by 9 feet; depth 7½ feet at north end and 17¼ feet at south end.	*160 †198	5 feet below the surface, 201.	62	Aug. 18, 12.50 p. m.	Putting a pole in the spring caused violent boiling.
21	Kitchen Spring	3 by 5 feet, with two openings; *a* is 2 feet, 8 inches in depth, *b* is 4 feet.	*a* 196 *b* 198	2 feet below the surface in *b*, 196; 3 feet down in *b*, 199.	60	Aug. 18, 12.15 p. m.	This spring is constantly boiling, and one of the orifices was used for cooking purposes. There is a red deposit about it.
22	Black Boiler	2½ by 1½ feet, 4 feet deep	198	2 feet below the surface, 200.	62	Aug. 18, 1 p. m	Has an ornamental rim and red deposit in outlet. Pool is lined with reddish deposit.
23		9 by 12 feet, 10 feet deep	189	4 feet below the surface, 189; 9 feet below the surface, 189.	61	Aug. 18, 1.13 p. m.	Deep, cavern-like pool, with red gelatinous deposit in outlet; sky-blue tint in deep basin at one end.
24	Yellow Boiler	4 by 3 feet, about 1 foot in depth.	194		61	Aug. 18, 1.15 p. m.	
25	Leather Spring	10 feet in diameter	135 to 145		60	Aug. 18, 3 p. m	Coated and lined with a brown, leathery, looking deposit.
26		2 feet in diameter, 6 inches deep	189		61	Aug. 18	Grayish-lined pool.
27		3½ by 5 feet, 5½ feet deep	115		61	Aug. 18	Water is 3 feet below the top.

*In the pool. †In the spring.

DESCRIPTION.

The *Taurus Spring or Geyser* is almost circular, measuring 6 by 7 feet. It has an ornamental border raised a few inches above the general surface. This border is brown and orange colored on top, changing into blackish-gray, and finally deep black below. The water as viewed from above is inky-hued, with a slight greenish tinge. The spring is situated on a mound, and is surrounded by pools which are pinkish, and have islands of white and also grayish depressions. The main outlet is to the westward, and is bordered by a white-capped edge, overrun by pinkish streaks broken with greenish and saffron lines at the edge. The water flows over terraces as it proceeds, which have broad belts of olive green with golden browns, and patches where dark browns predominate, and border lines of pink, salmon, and white. The east outlet is creamy red, with light olive-green and yellowish pools. Outside of the spring the prevailing tint of the deposits is white, with blue and brown grays. These notes will give a faint idea of the coloring surrounding the springs of this geyser basin. The flow from the spring is small in amount, and is through the western outlet into Shoshone Creek. The spring is one that is constantly boiling. The temperature at the surface was 196°. At a depth of 3 feet below the surface the temperature increased to 197°. At 6 feet it was 202°, and at 8½ feet 204°.

Marble Cliff Spring (Plate XXXI) measures about 11 by 23 feet, and has a narrow, shallow basin on three sides, which break off by cliff-like masses into the deep portions of the spring, in which the water has a deep indigo tint. The surface temperature was 163° F., and at the depth of 8 feet it was 166° F., the air being at 64° F. The spring is perfectly quiet.

The *Impenetrable Spring*, near the Union Geyser, is 10 by 14 feet, and has a depth of 19½ feet. The surface of the water is about 8 feet below the top of the deposit on the south and west sides. Next to the Union Geyser the deposit appears to have been washed away, and the rim here rises only from 2 to 5 feet above the level of the water. Professor Bradley, in 1872, considered this spring with the cones of the Union Geyser as occupying the mouth of an old and once powerful geyser, and thought it possible that it might still spout. We saw, however, no evidence while we were in the basin, nor did it show any sympathy with the eruptions of the Union Geyser. This corresponds also with the observations of Professor Bradley. There are three points of ebullition, but the boiling is not violent, and at times the spring is perfectly quiet. In the walls of this spring the laminated character of the siliceous deposit is well shown. Some of them contain nodules of harder deposit, which is almost opalized. The temperature, both at the surface and at a depth of 5 feet, was 196° F.

Kitchen Spring.—This spring was so named from the fact that during our stay in the Shoshone Geyser Basin it was utilized almost every day by our cook. The spring has two openings, in which the water is constantly boiling. The largest measured about 18 inches in diameter—just large enough to allow a kettle to be sunk in it.

Springs No. 18 and No. 20 were among the handsomest in the group, the water in the former having a yellowish-green tint, and in the latter deep-blue. There is a large pool of standing water surrounding No. 20, and on this a number of grasshoppers were found that had been coated with the deposit and preserved in form.

The table of the group preceding this description gives all the re-

CRATERS OF UNION GEYSER SHOSHONE BASIN

maining particulars, the numbers corresponding with those given on the map.

Union Geyser (Plate XXX).—This is the most important geyser in the Shoshone Basin. It has three small mounds or craters close together, each of which has an opening or vent. The central one is the principal geyser. Professor Bradley says: "We called this the Union Geyser because of its combination of the various forms of geyseric action." The three craters spout simultaneously, although the smallest one is insignificant in its action.

The central cone is about 3 feet high, and has a circumference of 18 feet at the base. The geyserite composing it is beautifully beaded on the outside, the color grading from yellow into gray, with pearly tints. On the top of the cone is a triangular orifice measuring 28 inches on each side. This opens into a globular cavity, which is nearly 5 feet deep and about 3 feet in diameter. It is brownish-yellow inside, and at the bottom is a hole about a foot in diameter. This is the outlet of the tube, and soon narrows and becomes crooked, so that we could not get an idea of its depth.

The north cone is next in size, and is about a foot in height. It has an irregular orifice measuring 2½ feet by 1 foot. It soon narrows as we go down. This cone is darker in color than the central one. The south cone is small, having a diameter of about 25 inches, and rising only about a foot above the general level. On the summit are two openings several inches in diameter. Between the central and south cones there is a small hole, from which water flows in the period between the eruptions. These cones are situated on a mass of gray and white deposit, which is laminated in its structure, and at places appears to be thin, as it is readily broken through. Professor Bradley, as I have said in another place, thinks that the cones of the Union Geyser, together with the Impenetrable Spring, occupy what was once the mouth of an immense geyser. The stream courses leading from the geyser are few, and it is only during the eruptions that there is overflow from the cones. The eruption begins with a few preliminary puffs of steam, which precede the spouting of the water only a few seconds. The first spurts of water attain a height of 10 or 15 feet. It rapidly rises to 100 feet or more from the central cone. In the small south cone it lasts a few seconds and is followed by steam, which escapes gently, while the other cones are in active eruption. In the central cone the water period is about 5 minutes, and in the north cone 10. Steam follows the water in both, escaping with a steady roar that continues several minutes after the water is exhausted in the north cone. This steady volume of steam changes to puffs at intervals of a few seconds, which gradually diminish until the eruption is ended. So gradual is the diminution that it is difficult to say when the eruption ends. The column of water and steam is projected steadily with great force.

The following transcription of my field-notes will present all the facts concerning the Union noted during our visit to the Shoshone Geyser Basin:

August 14.—We reached the Shoshone Geyser Basin early in the afternoon and camped near the Union Geyser. The craters of the geyser are full, and in the central one it spurts at intervals to the height of a foot or more.

August 15.—At 6.45 p. m. an eruption began, all the cones sending up water, that in the smallest lasting but a short time. In the middle cone it lasted about 5 minutes. At 6.56 p. m. the water in the north cone became exhausted and the steam came out in volumes with a steady roar,

which had ceased at 7 o'clock. At 7.05 p. m. the steam issued from the crater in pulsations at the rate of about 79 per minute. At 7.30 p. m. the pulsations were irregular and the intervals between them growing longer. At 7.50 p. m. the pulsations are about 16 to the minute, and the steam very much diminished in amount; at 8.05 p. m. they are very faint, and at 8.10 about ended. In the south cone, except at the very beginning of the steam period, the steam escapes gently. During the eruption the Impenetrable Spring was quiet. At 9.35 p. m. another eruption began, which resembled the one just described, except that at 9.52 there was a decided lull of a minute, after which the steam escaped in pulsations, followed at 10.10 p. m. by another stop. This was repeated until the end of the eruption, which lasted about an hour.

August 16.—3.40 a. m. an eruption began followed in about 10 minutes by a stop, after which steam escaped in pulsations as in the preceding eruption. The time of stoppage was not taken. At 6 a. m. the craters were found to be empty, and remained so during the day. From the central cone there was a slight escape of steam. At 7 p. m. water could be seen in the tube below the globular chamber of the central crater.

August 17.—Early this morning the water is in sight in the center crater. At 2.30 p. m. the following temperatures were taken.

Center cone: At surface of water, which is 4 feet below the top of the cone, has a temperature of 196° F.; 2 feet below the surface of the water the temperature is 201° F.

North cone: At surface of water, which is 3 feet below the top, the temperature is 197° F.; 1 foot below the surface it is 198° F. The temperature of the air during these observations is 630° F. In the south cone the temperature could not be taken.

August 18.—Center cone: At 11.30 a. m. the water is within 2 feet of the top, and the temperature at the surface is 198° F. Two feet below the surface the temperature is 200° F.; at 4 feet it is 204° F., and at 5½ feet the same, the temperature of the air being 60° F.

North cone: At 12 m. the water is within 1 foot of the top, and the surface temperature is 196° F., and 2 feet below it is 197° F.

In the south cone the water is too low to take the temperature, while in the small opening between the central and south cones the temperature is 191° F.

Center cone: At 3 p. m. the water is still 2 feet below the top, and the temperature 5 feet below the surface is 205° F., the air being 60° F.

August 19.—Center cone: At 8.40 a. m. the water is within a foot and a half of the top, and has a surface temperature of 197½° F., and at a depth of 6½ feet it is 205° F. It boils violently and there are occasional spurts over the edge. At 1 p. m. the water is within a foot of the top, with a temperature of 198° F., while 6 feet below the surface it is 207° F; temperature of air 55° F. At 6.40 p. m. the water is within 6 inches of the top, and at intervals spouts over the edge; the surface temperature is 200° F., and at 6 feet below it is 208° F. At 9 p. m. splutters and splurges with great noise.

North cone: At 8.40 a. m. the water is within 2 inches of the top and comparatively quiet, only a few bubbles occasionally escaping. It overflows at 6.40 p. m.

South cone: The water rises and falls in pulsations. The temperature is 194 at 8.40 a. m. In the vent between the center and south cones the water also pulsates.

August 20.—Center cone: At 8.25 a. m. the water boils vigorously, spouting over the edge. The surface temperature is 200° F.; 6 feet below surface, 208° F. This spouting kept up during the day, and the temperatures at 6.30 p. m. were, at the surface, 199° F., and 6 feet below, 208° F.

MARBLE CLIFF SPRING. SHOSHONE BASIN.

North cone: Water at 8.25 a. m. is bubbling and spurting, and has a surface temperature of 198° F. Four feet below the surface the temperature is 204. The south cone spouts a few feet above the top of the cone.

August 21.—During the night the geyser has been in constant agitation, with a great deal of noise.

At 7.46 a. m. eruption began.

7.51 a. m., water ends in center cone and steam comes out in great volumes with a steady roar.

7.56½ a. m., water period ends in north cone.

7.58 a. m., the roaring noise ends.

8.48 a. m., the eruption ends with the exception of a few puffs at long intervals.

The maximum height reached was 114 feet. During the playing the column was deflected 6° from the perpendicular by a strong wind. The spray produced a beautiful rainbow.

At 10.10 a. m. no water could be seen in any of the cones, although the sound of boiling far below could be heard.

Center cone: 10.36¼ a. m. steam begins to come out in puffs.

10.37 a. m., first spurts of water, reaching 10 or 15 feet, followed by eruption.

10.45 a. m., water stops in the center cone and the steam roar begins.

10.54.0. a. m., lull.

10.54.45 a. m., perfectly quiet.

10.55.15 a. m., begins puffing steam.

11.00.50 a. m., lull.

11.1.0 a. m., begins again.

11.5.30 a. m., lull.

11.5.50 a. m., puffs steam.

11.11.20 a. m., lull.

11.11.35 a. m., puffs steam.

11.12.50 a. m., lull.

11.13.5 a. m., puffs.

11.14.20 a. m., lull.

11. 14.30 a. m., puffs.

11.15.5 a. m., lull.

11.15.15 a. m., puffs.

11.15.52 a. m., lull.

11.16.3 a. m., puffs.

11.16.43 a. m., lull.

These keep up for some time, gradually growing fainter until the eruption of steam is entirely over.

7.46.30 p. m., there is a pumping sound, as though an eruption were about to take place. This is about the time it ought to occur.

7.48, the pumping sound ends.

North cone: 10.38 a. m., water eruption begins.

10.43 a. m., full jet is projected.

10.45 a. m., maximum, 66 feet, attained.

10.48 a. m., water stops.

10.49 a. m., spurt of water.

10.49.45 a. m., end of water eruption.

August 22.—At 8 a. m. the water is in sight at the bottom of the center cone and can be seen actively boiling in the north cone.

Evening: Water has been rising during the day.

August 23.—At 8 a. m. the water is within two feet of the top in the center cone. The surface temperature is 199° F., 5 feet below the surface it is 206° F. Water is flowing from the vent between the center and south cones.

5.55 p. m., the water in the center cone is within a foot and a half of the top, and the surface temperature is 198° F., 5½ feet below it is 207° F.

August 24.—During the night the geyser has been making a great deal of noise, and the north cone and the vent between center and south cones have been overflowing.

August 25.—At 8 a. m. the center cone spouts over the edge at intervals, the water is within a foot of the top, and has a surface temperature of 199°, and 6 feet below 207°.

August 26.—An eruption of the geyser was expected this evening, but has not taken place.

August 27.—We left the Shoshone Basin about 9 a. m., and up to that time no eruption had taken place, although the water is in violent agitation and kept so throughout the night.

The following is the description of the eruption of the Union Geyser given by Professor Bradley in 1872:*

During eruptions the west (south) vent spouts a little water 2 or 3 feet high, for from 1 to 2 minutes, and then yields a moderate flow of steam. Meanwhile the center vent is throwing a very powerful jet from 70 to 90 feet into the air, which, after about 5 minutes, gradually gives place to steam, the mingled steam and water giving the highest jets. The east (north) vent, spouting from 10 to 50 feet, throws a solid boby of water for about 10 minutes, when the whole supply of water seems to be exhausted, and the rush of steam from all the vents becomes more violent and continues some 40 or 50 minutes longer, gradually declining, however, though with many spasmodic renewals. A small, flat opening in the space between the central and western (southern) vents gives exit to a little water while the geyser is preparing for eruption, but takes no part in the eruption itself.

This description of the eruptions in 1872 answers very well for those noted in 1878.

The following table gives the eruptions witnessed by Professor Bradley in 1872:

No.	Eruption began.	Length of water eruption.	Total length.	Height.	Interval between beginnings.
	h. m. s.				*h. m. s.*
1	10 28 00 a. m.	5 minutes in the central cone, 10 minutes in east (north) cone.	47 minutes....	70 to 92 feet from the central cone, 10 to 50 feet from east (north) cone.	....
2	1 55 00 p. m.	.....	56 minutes...	70 feet.	3 27 00
3	10 25 00 p. m.	.....	.....	.....	8 30 00

The following table notes the eruptions of 1878 seen by us:

No.	Date.	Eruption began.	Length of the water eruption.	Total length.	Height.	Interval between beginnings.
		h. m. s.		*h. m. s.*		*d. h. m. s.*
1	Aug. 15, 1878	6 45 00 p. m.	5 minutes in the central cone, 11 minutes in the north cone.	1 25 00	Maximum; 107 feet in center, cone; maximum, 35 feet in north cone.	.....
2	Aug. 15, 1878	9 35 00 p. m..	Not taken.....	1 00 00	Not taken.....	2 50 00
3	Aug. 16, 1878	3 40 00 a. m..	Not taken.....	Not taken.	Not taken.....	7 05 00
4	Aug. 21, 1878	7 46 00 a. m..	5 minutes in central cone, 10 minutes 30 seconds in north cone	1 02 00	Center cone, maximum, 114; average 61. North cone, maximum, 56 feet.	5 4 06 00
5	Aug. 21, 1878	10 37 00 a. m.	8 minutes in the central cone, 12 minutes, 45 seconds in north cone.	Not taken.	Center cone, maximum, 108 feet; average, 59 feet. North cone, maximum, 66 feet; average, 42 feet.	3 11 00

From these observations it is of course impossible to deduce the period of the geyser, although it seems to have three eruptions separated

* Report U. S. Geol. Survey for 1872, p. 245.

FIG. 12.—Union Geyser in action, August 21, 1878, 7:46 a. m.

by intervals of about 3 and 7 hours. After the fifth eruption we expected one about 6 or 7 o'clock in the evening, but it did not take place, nor did one take place on the 26th as we expected. It is probable, however, that if the observations could have been carried on long enough a regular irregularity would have been observed, *i. e.*, the law of the irregularity would be determined.

In the interval between eruptions 1 and 2, and 2 and 3 and between 4 and 5, the craters remained empty, while during the five days intervening between 3 and 4 the cones, or craters, gradually filled. Nos. 1, 2, and 3 ought, therefore, to be considered as different periods of the same eruption, and 4 and 5 as periods of another.

Twenty-four hours and fifteen minutes after the first eruption began water was observed at the base of the central crater; and at the end of 2 days and 16 hours it was within 2 feet of the top.

After the second eruption (No. 4 in the table) it was also 24 hours and 14 minutes after the beginning before the water was noticed at the bottom of the central cavity, and 2 days and 10 hours when it was within 2 feet of the top. For more than a day preceding the action of the geyser the water is in violent agitation and spurts several feet above the cone. Too few eruptions were seen to enable us to determine the length of this period of agitation. If it had been seen only when in this condition it might have been classed with those springs that are constantly agitated. It is probable that many of the springs so classed may be true geysers with long intervals. In most cases, however, the appearance of the surrounding deposits will enable one to judge of the character of the spring.

The discrepancy in the two tables just given as to the total length of the eruption is probably due to the uncertainty as to when it is ended, as the alternation of puffs and quiet periods decline so gradually that it is difficult to determine the exact end of the eruption. In eruptions Nos. 1 and 4, which were really the beginnings of two separate eruptions, the steady roaring was marked; but in Nos. 2, 3, and 5 there was a marked difference, periods of perfect quiet distinguishing them very soon after the eruptions began.

The temperatures were taken with a maximum self-registering thermometer, which was placed at the end of a graduated pole.

Table of temperatures of Union Geyser taken in 1878.

Date.	Center-cone.							North cone.			Vent.	South cone.
	Surface temperature.	2 feet below surface.	5 feet below surface.	5½ feet below surface.	6 feet below surface.	6½ feet below surface.	Temperature of the air	Surface temperature.	2 feet below surface.	4 feet below surface.	Surface.	Surface.
August 17:	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
2.30 p. m	196	201	.....	.....	.....	.....	63	197	.....	198	.....	.....
August 18:												
11.30 p. m	198	204	204	.....	.....	.....	60	196	197	air, 62	191	.....
3.00 p. m	.....	.....	.....	205	.....	.....	60	.....	.....	.....	.....	.....
August 19:												
8.40 a. m	197½	.....	.....	.....	.....	205	55½	.....	.....	.....	.....	194
1.00 p. m	198	.....	.....	.....	207	.....	60	.....	.....	.....	.....	.....
6.40 p. m	200	.....	.....	.....	208	.....	57	.....	.....	.....	.....	.....
August 20:												
8.25 a. m	200	.....	.....	.....	208	.....	58	198	.....	204	.....	.....
6.30 p. m	199	.....	.....	.....	208	.....	58½	.....	.....	.....	.....	.....
August 23:												
8.00 a. m	199	.....	206	.....	.....	.....	57	.....	.....	.....	.....	.....
5 55 p. m	198	.....	.....	207	.....	.....	61½	.....	.....	.....	.....	.....
August 25:												
8.00 a. m	199	.....	.....	.....	.....	207	46½	.....	.....	.....	.....	.....

The only temperature taken in 1872 was 198° F. It was found impossible to take the temperature immediately preceding the eruption, as the agitation of the water was too great. The table shows that the temperature of the air has no appreciable effect on the temperature of the water in the geyser, as with some of the lowest air temperatures the highest temperatures were observed in the geyser. The surface temperature shows a gradual rise from the 17th to the evening of the 20th, an eruption taking place the following morning. These temperatures, with the exception of the first (196° F.), are either close to or above the theoretical boiling-point, which is 198.2° F., as deduced from hirty-six barometrical readings. The boiling-point, obtained by plunging the thermometer in boiling water, in camp, is about a tenth of a degree lower than the theoretical point just given. It is evident, then, that the water in the geyser is superheated by the steam from the depths below, which escapes through the water. The deep temperatures (which are the deepest obtainable) also show a gradual increase at first and then a maintenance of 208° F. for a couple of days before the eruption. After the eruption it rose again steadily to 207° and it is probable if the temperatures had been observed later 208° might have been observed.

CAMP GROUP.

This group includes a few springs near the river, which were near our camp. They are enumerated in the following table:

No. and name.	Size and depth of spring.	Surface temperature.	Deep temperatures.	Temperature of air.	Time of observation.	Remarks.
		°F.		°F.		
1. Wash-tub.	12 by 9 feet; basin 6½ feet deep.	179	5 feet below surface in the basin, 177. 6 feet below surface at tube, 185.	63	1.50 p. m.	Large yellow-lined basin, with a tube leading downward from it. It was used as a wash-tub.
2.	4 by 5 feet; 3½ feet deep.	159	2½ feet down, 159	64	2.00 p. m.	Rather quiet spring, with drab-colored deposit; a few bubbles escape occasionally.
3.	3 by 3 feet; basin 2 feet deep.	192	6 inches below surface, 194.	63	2.10 p. m.	The water is 8 inches below the top and is in constant agitation, spouting about a foot.
4. Lavender spring.	3 by 3 feet	190		62	2.15 p. m.	Mud spring, with thin, boiling mud.
5.	5 by 2 feet; 6½ feet deep.	166	5 feet below the surface, 168.	63		There are two openings to the main spring, and near it are two vents.
6.	8 by 15 inches; 2½ feet deep.	(*)				An old geyser mound and tube, evidently full of water at times; near it is an extinct crater.
7.						Hole in the side of the hill.

* Not taken.

MINUTE MAN GROUP.

The Minute Man Group is on the east side of Shoshone Creek, about 500 or 600 feet north of the Orion Group. The Minute Man Geyser, from which the group is named, is about in the center of the group, and is

700 feet from the Taurus Spring, which is the most northern of the Orion Group. The nearest spring is only about 300 feet from the Taurus. At the north end the group merges into the Little Giant Group. There are over thirty springs in the group, several of which belong to the class of geysers, while others are boiling springs.

Minute Man Geyser (Plate XXXII).—This geyser was named by Professor Bradley in 1872. It is about 250 feet east of the creek, situated on a mound of geyserite, at the foot of the hills that stand between the creek and the lake. It has a crater that is very irregular in shape, somewhat like that of Old Faithful in the Upper Basin, on the Fire Hole or Madison River. It is from 3 to 5 feet in height and 46 feet in circumference. The throat or opening is 3 by 2½ feet, and lined with globular masses of gray and yellowish-gray colors. The basin in this crater is about 8 feet in depth. The outside of the crater is beautifully beaded and the colors grays, buff and white, with pearly-gray beaded basins. The ornamental beadwork extends for a considerable distance beyond the crater. At the base of the crater, between it and the hill, is a beautifully ornamented pool, measuring 26 by 10 feet. It has a yellow basin 4 feet 4 inches deep. This sometimes spouts, but the interval and height were not determined. Most of the water from the geyser flows into this pool, but I was unable to tell what effect it has upon it. Sometimes it remained full of water during the eruption of the Minute Man, and at others it was entirely empty. Professor Bradley's observations in 1872 seemed to show that it was emptied by the eruption of the Minute Man. On the top of the crater of the Minute Man are several sulphur-lined vents, which appear to be independent of the geyser. The eruptions of the Minute Man consist of *spurts* of water. The main mass of water does not attain a very great elevation. The spurts reached 23 feet at the highest, as measured by us from the end of a 50-foot base line. The column or rather mass of water inclines towards the creek. Almost all the water flows back into the pool. None of the observations determined any regularity in the action of the geyser.

Professor Bradley gives the following description of the eruptions in 1872:

> These occur pretty regularly for some hours, at intervals of from 2 to 3 minutes, but gradually decline in force, until the supply of water becomes exhausted. Then the geyser is silent for several hours, until all the crevices, as well as the surface-pools, are again filled with water, when its eruptions recommence with much violence, the jets then reaching altitudes of from 30 to 40 feet. These again decline, and the series of phenomena is repeated.*

The following is a transcription of my notes on the geyser:

August 14.—The Minute Man has spouted frequently during the day to a height of 10 or 15 feet, but no time observations have been made.

August 15.—The geyser was in action this morning, but seems to have been quiet most of the day.

August 16.—About two hours' observations were made on the Minute Man to-day, while the surrounding springs were being examined. The pool back of the geyser was full of water, and quiet, having a temperature of 177° F., with the air at 61° F.

The following table gives the eruptions witnessed, with the interval, length, and height of a number of these spurts:

*Report U. S. Geol. Survey for 1872, p. 246.

Observations August 16, 1878.

Eruption began.	Interval between eruptions.	Length of eruption.	Height of column.
h. m. s.	*m. s.*	*Minutes.*	*Feet.*
11 47 00 a. m.	.....	¼ to ½	Not taken.
11 49 30 a. m.	2 30	¼ to ½	Do.
11 51 00 a. m.	1 30	¼ to ½	Do.
11 53 00 a. m.	2 00	¼ to ½	Do.
11 55 00 a. m.	2 00	¼ to ½	Do.
11 56 30 a. m.	1 30	¼ to ½	Do.
11 58 00 a. m.	1 30	¼ to ½	Do.
12 01 00 a. m.	3 00	¼ to ½	Do.
12 02 30 p. m.	1 30	¼ to ½	Do.
12 04 00 p. m.	1 30	¼ to ½	Do.
12 05 00 p. m.	1 00	¼ to ½	Do.
12 06 05 p. m.	1 5	¼ to ½	9
12 06 40 p. m.	0 35	¼ to ½	16
12 08 15 p. m.	1 35	¼ to ½	14
12 09 15 p. m.	1 00	¼ to ½	
12 10 10 p. m.	0 55	¼ to ½	14
12 11 00 p. m.	0 50	¼ to ½	16
12 11 45 p. m.	0 45	¼ to ½	23
12 13 20 p. m.	1 35	¼ to ½	19
12 15 10 p. m.	1 50	¼ to ½	23
12 17 10 p. m.	2 00	¼ to ½	18
12 19 05 p. m.	1 55	¼ to ½	13½
12 19 50 p. m.	0 45	¼ to ½	15
12 20 50 p. m.	1 00	¼ to ½	18
12 22 15 p. m.	1 25	¼ to ½	15
12 23 00 p. m.	0 45	¼ to ½	13½
12 24 00 p. m.	1 00	¼ to ½	19
12 25 00 p. m.	1 00	¼ to ½	15
12 26 30 p. m.	1 30	¼ to ½	18
12 29 00 p. m.	2 30	¼ to ½	16
12 30 30 p. m.	1 30	¼ to ½	18
		Seconds.	
12 31 15 p. m.	45	10	15
12 32 15 p. m.	1 00	10	11½
12 33 00 p. m.	0 45	10	17
12 34 30 p. m.	1 30	10	17
12 36 30 p. m.	2 30	10	16
12 38 00 p. m.	1 30	10	18
12 39 30 p. m.	1 30	5	16
12 41 00 p. m.	1 30	5	15
12 42 15 p. m.	1 15	15	19
12 44 05 p. m.	1 50	5	8
12 44 50 p. m.	0 45	15	21½
12 47 25 p. m.	2 35	20	18
3 30 45 p. m.	.....	.....	Not taken.
3 32 30 p. m.	1 45	30	Do.
3 34 45 p. m.	2 15	3	Do.
3 38 00 p. m.	3 15	10	Do.
3 41 52 p. m.	3 52	3	Do.
3 43 20 p. m.	1 28	.....	Do.
3 43 53 p. m.	0 33	10	Do.
3 46 15 p. m.	2 22	5	Do.
3 47 56 p. m.	1 41	3	Do.
3 49 55 p. m.	1 59	6	Do.
3 51 30 p. m.	1 35	9	Do.
3 52 52 p. m.	1 22	8	Do.
3 54 15 p. m.	1 23	16	Do.
3 56 26 p. m.	2 11	9	Do.
3 58 04 p. m.	1 38	8	Do.
3 59 28 p. m.	1 24	9	Do.
4 1 14 p. m.	0 46	11	Do.
4 2 49 p. m.	1 35	2	Do.
4 3 05 p. m.	0 16	4	Do.
4 3 48 p. m.	0 43	7	Do.
4 5 40 p. m.	1 52	6	Do.
4 6 34 p. m.	0 54	7	Do.
4 8 03 p. m.	1 29	13	Do.
4 10 12 p. m.	2 9	5	Do.
4 12 23 p. m.	2 11	18	Do.
4 15 08 p. m.	2 45	7	Do.
4 17 10 p. m.	2 2	10	Do.
4 19 00 p. m.	1 50	4	Do.
4 20 30 p. m.	1 30	15	Do.
4 23 03 p. m.	2 33	7	Do.
4 24 50 p. m.	1 47	10	Do.
4 26 51 p. m.	2 1	15	Do.
4 29 18 p. m.	2 27	11	Do.
4 31 20 p. m.	2 2	8	Do.

MINUTE MAN GEYSER SHOSHONE BASIN.

August 18.—Eruptions to-day have occurred as usual, but the water in the pool back of the geyser has been low whenever seen.

In the table of observations taken on the 16th, it will be seen that 43 spurts occurred in an hour in the morning, while in the afternoon there were only 34 to the hour. It is probable that at times the height attained may be 30 or 40 feet, although the highest measured by us was only 23 feet above the top of the mound. There appears to be no regularity about the length of the spurt nor of the interval between them. The steam appears to escape rapidly, causing the frequent spurts. The following temperatures were taken:

	°F.
August 16.—2½ feet below top of crater	180
5 feet below top of crater	187
6 feet below top of crater	200
6 feet below top of crater	200½

These temperatures were all taken immediately after spurts. The water was in such constant agitation that it was impossible to say how far below its surface these temperatures were taken. It was difficult to take the temperatures that were obtained. The temperature in the pool back of the geyser was 171° F. The temperature of the air during these observations was 61° F.

Shield Geyser.—The Shield Geyser (shown in the foreground to the left in Plate XXXII*a*) was named in 1872. It is about 70 feet from the Minute Man, which is seen in the background of the illustration, towards the north, and has a beaded mound, which is from 18 inches to 2 feet above the general surface. It measures about 11 by 7½ feet. It has a shield-shaped basin, which is brilliant white, and measures about 8 feet on two sides and 7 on the third. At the bottom is an opening about 3 feet in diameter, which is the top of the tube. A depth of 5 feet 8 inches was measured. The following are the observations made:

August 16.—While observations were being made on the Minute Man, the basin of the Shield was full, and every few seconds the water spouted a foot or two. At 1.2.00 p. m. the basin was empty; at 1.3.00 it was filling, and surface temperature was 190° F., air 60° F.

Time of observation.	Intervals.	Interval from one emptying to another.
h. m. s.	*m. s.*	*m. s.*
1 02 00 p. m., basin is empty		
1 03 00 p. m., basin is filling	1 00	
1 13 00 p. m., basin is empty		
1 16 00 p. m., basin is filling	3 00	
1 18 30 p. m., basin is empty	2 30	5 30
1 20 00 p. m., basin is filling	1 30	
1 22 00 p. m., basin is empty	2 00	3 30
1 23 00 p. m., basin is filling	1 00	
1 27 00 p. m., basin is full and spouts 3 or 4 feet	4 00	
1 30 00 p. m., basin is empty	3 00	8 00
1 35 00 p. m., water is down several inches in the tube		
1 40 00 p. m., water still down in tube		
1 50 00 p. m., water still down in tube		
2 00 00 p. m., water still down in tube		
3 25 00 p. m., visited the Shield and found the basin full and water spouting two or three feet, as in the morning; considerable overflow		
4 13 00 p. m., water down in the tube		
4 15 00 p. m., basin filling and bubbling	2 00	
4 16 00 p. m., spurting as usual	1 00	
4 21 00 p. m., quiet and water falling	4 00	
4 23 00 p. m., water down in tube boiling moderately	2 00	10 00
4 24 00 p. m., basin filling	1 00	
4 25 30 p. m., basin is full but not spouting	1 30	
4 26 30 p. m., water is falling	1 00	
4 28 00 p. m., water is down in the tube	1 30	5 00
4 29 00 p. m., water is rising	1 00	

The following temperatures were taken, all on the 16th of August, with the air at 60° F.

1 3 p. m., 196° F. at the surface; 196½° F. 4 feet below.

1 16 p. m., 196½° F. at surface, just before the basin is full.

1 22 p. m., 197° F. 2 feet below the surface.

The outlet from the Shield is brilliant white and lined with pearly pebbles. When the spring is in action there is considerable overflow, which runs towards the Rosette.

Gourd Geyser.—The Gourd, shown in the foreground of Plate XXXII *a*, was named from its shape. It is close to the Shield, with which it appears to be in sympathy. Whenever the water was low in the former it was lower than usual in the Gourd, although the boiling continued. The opening is irregular, having a length of about 8 feet. The crater is 10 feet long. The broad portion of the gourd-shaped opening is about 5 feet in diameter, while the narrow neck and crooked portion measure from about 1 foot to 2 feet in width. Globular masses line the neck, and beyond the end are flat basins in which the water stands. It is constantly boiling, the points of ebullition being mainly in the broad portion of the gourd. It is doubtful if there is any sympathy between the Minute Man and either the Shield or Gourd.

The following temperatures were taken August 16, with the air at 60° F.:

	° F.
Surface	196
5 feet below the surface	199
7 feet below the surface	200

The last temperature was taken in rather quieter water than were the others. The amount of steam escaping from the Gourd appeared to be greater than that from the Shield. The amount of depression in the water of the Gourd was always rather slight.

Rosette Spring.—This spring was named in 1872, and lies between the Shield and the hill. It is a beautiful, cavern-like spring, 30 feet long and 17 feet wide at the widest part, and 13 feet deep. The border is rosette-bordered, as is the outlet. The opening of the spring is about half the size just given. The colors of the spring are blue, green, and greenish-blue. The lining of the basin is arranged in scalloped scales, overlapping like scales in a coat of mail. On these scales was a coating of sulphur, the color of which increased the beauty of the spring. In the shallower basin the tints were light-pearl and blue-grays, fading into pinkish-pearl grays. The spring, whenever noticed, was quiet and had a surface temperature of 166½° F. at 1.30 p. m., air 59° F. The temperature at a depth of 7 feet was the same as at the surface. Back of the Rosette is another pool of about the same size, viz, 30 by 18½ feet. It has a rather shallow basin, lined with a leather-like deposit. The temperature was only 149° F.

On the flat space at the foot of the hill, back of this pool, there were several bubbling points.

The hill back of the Minute Man also has a number of steam vents and hot holes.

No. 15. *The Little Bulger Geyser.*—This geyser, which is across a small knoll from the Rosette, was called the Bulging Spring in 1872. I have renamed it as a true geyser, although not a very large one. It has a flat, depressed basin, about 11 by 15 feet, from which a beautiful yellow-lined outlet or water-way takes the overflow when the geyser is in action. In the center of this basin the opening is 8½ feet in diameter, very rapidly diminishing in size downward. The following notes on the eruptions

GOURD, SHIELD AND MINUTE MAN SHOSHONE BASIN

were taken. Eruptions on August 19 occurred at 9.25 a. m. and at 9.50 a. m.:

No. of eruption.	Time of observation.				Interval from beginning to beginning.	Length of spouting.	Height of column.	Temperature.
				AUGUST 19.				
	h.	*m.*	*s.*		*m.*	*m. s.*	*Feet.*	°F.
1	9	57	00	a. m. basin begins to fill				
	10	00	00	a. m. water overflows				172
	10	02	00	a. m. steam bulges				175
	10	02	30	a. m. spouting begins			5 to 6	184
	10	04	00	a. m. eruption ends and water goes back		1 30		
	10	05	00	a. m. water is low				177
2	10	09	00	a. m. water begins to rise	12			
	10	11	00	a. m. outside basin begins to fill				170
	10	13	30	a. m. water overflows				
	10	15	00	a. m. steam bulges				
	10	16	00	a. m. spouting begins				184
	10	16	30	a. m. spouting				184
	10	17	00	a. m. end of spouting		1 00		
	10	18	00	a. m. water goes back into small inside basin				
3	10	23	00	a. m. water begins to rise	14			167
	10	23	30	a. m. a few bubbles escape				
	10	24	00	a. m.				175
	10	26	00	a. m. water overflows				176
	10	27	00	a. m. steam rises				
	10	27	30	a. m. steam bulges				178
	10	28	30	a. m. begins to spout				
	10	29	00	a. m. spouting			5 to 6	185
	10	30	00	a. m. spouting ends (water still overflows)		1 30		184
	10	31	00	a. m. water goes back				
	10	32	00	a. m. water is in small basin				174
	10	33	30	a. m. the geyser is perfectly quiet				
4	10	35	00	a. m. water begins to rise	12			166
	10	36	00	a. m. slight bubbling				
	10	37	00	a. m.				174
	10	38	00	a. m. bubbles become frequent				
	10	39	00	a. m. water overflows				
	10	40	30	a. m. bubbles violently				
	10	40	45	a. m. steam bulges				176
	10	41	00	a. m. begins to spout				
	10	42	30	a. m. spouts violently				185
	10	43	00	a. m. spouting ends		2 00		
	10	43	15	a. m. one bulge				
	10	44	00	a. m.				176
	10	44	30	a. m. water goes back into the basin				
	10	46	30	a. m. geyser is perfectly quiet				165
5.	10	49	00	a. m., water begins to rise	14			
	10	49	30	a. m., bubbles escape				
	10	52	20	a. m., water overflows				
	10	53	00	a. m., steam comes quickly				
	10	54	00	a. m., steam bulges				
	10	55	10	a. m., spouting begins			10	
	10	56	15	a. m., spouting stops		1 35		
	10	56	30	a. m., one spurt				
	10	56	45	a. m., spouting ends				
	10	57	50	a. m., water is quiet in the basin				
6.	11	7	00	a. m., steam bulges				
	11	8	00	a. m., spouting begins				
	11	9	30	a. m., spouting ends		1 30		

The following tables give some of the intervals for the eruptions observed:

	From beginning to bulging of stream.	From beginning to beginning of spouting.	From beginning to overflow.	From overflow to end of spouting.
	m. s.	m. s.	m. s.	m. s.
First eruption	5 00	5 30	3 00	4 00
Second eruption	5 00	6 00	4 30	4 30
Third eruption	4 30	5 30	3 00	4 00
Fourth eruption	5 45	6 00	4 00	4 00
Fifth eruption	5 00	6 10	3 20	4 25

	Interval from one bulge to another.	Interval from spurt to spurt.
	m. s.	m. s.
First to second	13 00	12 30
Second to third	12 30	12 30
Third to fourth	13 15	12 30
Fourth to fifth	13 15	14 10
Fifth to sixth	13 00	14 50

After the spouting is over it is usually a minute before the water retires.

As the tables show, the water begins to rise until the basin overflows. The eruption begins with a few bubbles of steam followed by bulges when the steam escapes with a sound like that of a liquid escaping from the bung of a barrel. This is soon followed by the spurting, which is to a height of 6 to 10 feet. When the water retires it appears to be sucked in as water is from a basin with a small aperture. As we have seen, the temperature increases from about 166° at the time when the geyser is quiet to 185° when it is in action, after which it decreases. Although the eruptions noted were few in number, the geyser appears to be very regular. Isolated eruptions were afterwards seen, but were found to correspond to those that have been given above in the tables.

No. 14, *Soap Kettle.*—This spring was named in 1872. Professor Bradley says (report for 1872, page 246):

> Forty feet beyond (the bulging spring), the Soap Kettle keeps up a furious boiling of colored water, more or less covered with foam, looking like dirty soap-suds Its basin is lined with a yellowish brown deposit. This has probably been a strong spouter, but now erupts only at long intervals, if at all.

In 1878 it was a circular basin of hard geyserite, measuring about 9 feet in diameter. The rim was about a foot in height. The inside sloped gradually to an irregular opening, measuring, approximately, 3 by 2 feet about 3 feet from the top. In this the water was constantly agitated with a surface temperature of 197° F., which increased to 197½° F. at a depth of 5 feet. The water rises at intervals of about a minute, and remains up from 15 to 30 seconds.

Black Sulphur Geyser.—This name was given in 1872 to three vents which are farther up the river, and appear to be constantly agitated. They have temperatures of 172½° F., 180° F., and 186° F.

The Twins were also named in 1872, but when we saw them they ap-

peared to be almost extinct. There was not sufficient water in sight to enable us to take their temperatures.

Nos. 23, 24, 25, 31, 32, and 33 are on the opposite side of the river from the Minute Man, while Nos. 26, 27, 28, 29, and 30 are a sub-group between the Minute Man and the Orion Group.

The following table gives all the points of interest in relation to them, while the map shows their position, the numbers corresponding:

Table of the Minute Man Group.

Number.	Name.	Size of spring.	Surface temperatures.	Deep temperatues.	Temperature of air.	Time of observation.	Remarks.
			° F.		°		
1	.....	5 feet wide.....	153	.....	61	Morning.	
2	.....	5 by 4 feet	178	.....	61	....do	Near the Shield geyser.
3	.....	5 by 6 feet	197	.....	61	....do	Square-cornered spring.
4	.....	6½ by 4 feet	105	.....	....	....do	Red pool that receives water from the Rosette and has a red-lined water-way which extends to Rosette.
5	.....	10 by 9 feet ..... 16 feet deep.	190	.....	....	....do	Light greenish tinted water.
6	.....	2½ by 2 feet	146–158 161 161 163	.....	....	....do	White-lined pool, with greasy-looking contents. It receives water from the Rosette through a red-lined water-way.
7	.....	Irregular fissure, 11 feet in length.	193	.....	....	....do	Close to river.
8	.....	2½ feet diameter...	163	.....	....	....do	This spring has a beautiful lemon-yellow colored water-way, and receives water from spring No. 3. It is partly spring and partly pool.
9	.....	9 by 3½ feet	193	.....	61	....do	Pear-shaped spring near the river.
10	.....	.....	145	.....	....	....do	Quiet circular spring.
11	.....	3 feet diameter....	113	.....	....	....do	Pool in the water-way from the Minute Man. A red-lined outlet leads to river.
12	.....	1½ feet by 1 foot...	195	.....	....	....do	Grey-lined spring near the Minute Man.
13	.....	18 inches diameter, 4 feet deep.	.....	.....	....	....do	Crater-like spring, in which the water is quietly bubbling.
14	Soap Kettle.	The cone is 1 foot high, 9 feet in diameter, spring inside is irregular 3 by 2 feet.	197	5 feet below the surface, 197½.	59	Afternoon.	Water is constantly agitated, and rises and falls at regular intervals.
15	Little Bulger.	Basin 11 by 15 feet; spring, 8½ feet diameter.	165–184	.....	59	....do	Spouting geyser.
16	.....	3½ by 2½ feet; 1 foot deep.	194	4 inches below surface, 196.	59	....do	Constantly boiling. The spring has a dark greenish drab colored basin.
17	.....	1 by 5 feet; 4 feet deep.	187½	3 feet below the surface, 191.	60	11.30 a. m.	The basin slopes to a deep hole at one side, and has a lead-colored deposit.
18	.....	2 by 4½ feet; 3 inches deep.	125	.....	59	11.15 a. m.	Quiet spring, which receives water from No. 15.
19	.....	8½ by 11 feet; 7 feet deep.	185	6 feet below the surface, 187.	61	11.45 a. m.	Water boils gently, and in the pool is turbid.
20	.....	Spring 1 by 2½ feet; 4 feet deep; fissure, 5 feet by 4 inches.	197 184	3 feet below surface, 197½.	61	11.50 a. m.	

Table of the Minute Man Group—Continued.

Number.	Name.	Size of spring.	Surface temperatures.	Deep temperatures.	Temperature of air.	Time of observation.	Remarks.
			° F.		°		
	Black Sulphur.	1, 2 by 2 feet, 3 inches deep.	172½	.....	....	11.45 a. m.	Three vents, all boiling.
		2, 3 by 4 feet; 1 foot deep.	180	.....	....		
		3. 3 by 6 feet; 4 feet deep.	186	3 feet below surface, 186½.	61		
21	Twins	Cones 3 feet deep	.....	.....	60	.....	Cones are about 6 inches high, and water out of sight.
22	.....	3 by 4 feet	163	.....	60	12 m	Small pool surrounded with geyserite.
23	.....	5½ by 7 feet.....	121	.....	....	.....	Red pool with three white lined orifices in the basin.
24	.....	Fissure 11 by 22 feet.	180	.....	....	.....	There is a spring on the mound above the fissure. The fissure has a yellow basin.
25	.....	.....	.....	.....	....	.....	Dry steam holes.
26	.....	13 by 17 feet; spring, 1 foot deep basin, 4 inches deep.	124	.....	57	9.20 a. m..	This spring has a flat brown basin. The spring is quiet, with a slight escape of bubbles at intervals from the center.
27	.....	5 by 14 feet; 6 feet deep.	146	4½ feet below the surface, 146.	57	9 40 a. m.	The spring is lined with dark green and red confervoidea, and is cavern-like at one end.
28	.....	23 by 25 feet	154 156 161 154 158 140 115 133 123	.....	57	9 15 a. m.	A collection of mudholes and steam vents in which there is generally light-colored mud.
29	.....	7 feet diameter ...	110	.....	....	.....	Dead pool on edge of river.
30	.....	18 by 13 by 12 feet.	....155 136 130 145 150 130 128	.....	....	.....	Seven springs concealed in the grass, some nearly extinct; most of them are mudholes.
31	.....	Fissure, 1 by 2½ feet.	.....	.....	....	.....	Has a yellow lined basin on a mound of geyserite.
32	.....	17 by 11 feet	166	.....	72	.....	Greenish-red basin, with white lined funnel in center. Pearl-gray border with irregular surface on the bottom.
33	.....	7 by 6½ feet	130	.....	72	.....	Dark red pool with grassy edge.
34	.....	.....	.....	.....	....	.....	A small oozing hole near Nos. 19 and 20.

THE LITTLE GIANT GROUP.

The Little Giant Group is really a continuation of the Minute Man Group, although the drainage from the springs so included is connected with that from the Little Giant Geyser, on which account I have considered them as a separate group. Nos. 15 to 22 are disconnected, forming a sub-group, which appear to drain in the opposite direction from those around the Little Giant. When we saw them they were mainly sulphur oozes in a large flat, although in wet seasons there are

probably numerous springs here. They are scattered over a flat, bare spot, with geyserite pebbles and sand which is bluish in color.

The Little Giant Geyser.—This geyser is in the center of a platform-like area of geyserite, measuring 68 by 79 feet. For a distance of about 10 feet around the geyser, or in a space of about 20 feet diameter, this platform is beaded with pink geyserite, which probably denotes the area on which the water falls while the geyser is in action. The crater is somewhat irregular in shape, although nearly square, measuring 3 by 4½ feet. The basin is 3½ feet deep and lined with brownish and red geyserite, which also forms a slightly raised rim around the geyser. The eruption takes place when the basin is full of water, and soon attains its maximum elevation of 10 to 50 feet, generally in about 2 minutes, and then dies down quickly, the entire eruption lasting from 13 to 28 minutes. After it dies down there are occasional spurts of a foot or so. There appear to be about two eruptions daily, but the geyser was not closely enough observed to determine the interval between the eruptions. The following were noted:

Date.	Eruption began.	Maximum attained.	Eruption ended.	Duration.	Height.
	h. m. s.	*h. m. s.*	*h.m.*	*m.*	*Feet.*
August 14	4 17 p. m.		4 30 p. m.	13	10–15
15	2 30 p. m.				
16	1 42 p. m.	1 44 00 p. m.	2 10 p. m.	28	50
17	8 25 a. m.				
17	6 05 p. m.				
18	11 00 a. m.				
19	11 20 30 a. m.	11 22 30 a. m.	11 45 a. m.	24½	
19	3 27 15 p. m.	3 29 p. m.	3 40 p. m.	12¾	25
20	10 00 a. m.				

The following is the transcription of the notes taken during the principal eruptions observed:

AUGUST 16.

During the morning the geyser has been quiet.

h. m.

1 42 p. m., eruption began.
1 44 p. m., eruption has attained maximum and begins to die down.
2 00 p. m., still throws some water.
2 10 p. m., eruption is ended.
The greatest elevation attained was 50 feet.

AUGUST 19.

h. m.

1 25 p. m., water is within a few inches of the top, and has a temperature of 192° F. at the surface and 193° F. 3 feet below the surface.
1 30 p. m., the water is within 2 inches of the top and is bubbling. The temperature 3½ feet below the surface is 200° F.

s.

3 27 15 p. m., eruption begins.
2 29 p. m., maximum 25 feet attained.
3 30 p. m., spouts only a foot above the crater, and has a temperature of 194½° F.
3 35 p. m., spouts 2 feet or more.
3 40 p. m., the geyser is perfectly quiet.
3 45 p. m., the water is 3 feet below the top.

The adjacent springs, Nos. 1 and 2, seemed to be in sympathy with the Little Giant, and were low when the water was down in the geyser, and while the geyser was filling these springs were in constant ebullition and spouting to a foot or two at intervals. There are no other springs in the group that call for special mention. They are all given in the following table with all the points noted.

Besides these springs there are several vents on the platform with the Little Giant.

Table of the Little Giant Group.

Number.	Size of spring.	Depth.	Surface temperatures.	Deep temperatures.	Temperature of air.	Time of observation.	Remarks.
			°F.		°F.		
1	14 by 20 inches.	2 feet	197		60	2.20 p. m.	It is on the platform of geyserite with the Little Giant, and has a small cone or hummock. It keeps bulging all the time.
2	20 by 32 inches.		155 164		60	2.25 p. m.	Two small holes on the platform with the Little Giant.
3	Not taken.		191		62	3.10 p. m.	The mound of this spring is coated with red gelatinous material, and the water comes from the main spring with a bulge which spurts it several feet into the air. There are several openings in active ebullition.
4	10 by 15 inches.	3 inches	105		62	3.15 p. m.	Small spring on mound.
5			153		62		
6			186				Small oozes on side of hill.
8	11 by 7 or 8 feet.	Irregular	*a*164 *b*192 *c*170 *d*174		62	3.20 p. m.	There is a pool with several openings.
9	2½ by 3½ feet.		176		62	3.30 p. m.	
10	15 feet long.	3 feet 3 feet 4½ feet	*a*180 *b*181 *c*181	2 feet down, 182. 1½ feet down, 182. 3 feet down, 185.	62	3.30 p. m.	Small gray pool. The main basin is light-colored and has 4 openings. Outside are three springs, one a cone and others muddy pools.
11	2½ by 3 feet.	2½ feet		1 foot down, 118	62	3.35 p. m.	
12	2½ by 6½ feet.	4½ feet	184	3 feet down, 189.	63		Quiet, dirty pool. The spring has straight, cliff-like sides, white in color, and the water outlet is red and yellow in its coloring.
13	1 foot by 9 inches.	A few inches.	178		63		A small, yellow sputterer in the waterway from No. 12.
14	*a*, 2 feet diameter.		120				
	b, 10 inches by 2 feet.		84		63	3.55 p. m.	Two small, quiet pools.
15							Sulphur oozes in the midst of confervoidea.
16	30 by 22 inches.		165		63		Yellow mud pots.
17			135		63		White geyserite ridge.
18			184		63		Sulphur ooze.
19			155		63		
20	3 by 4 inches.		74		63		Sulphur spring.
21			130				Water simply oozes from the earth.

SULPHUR HILLS.

Between Shoshone Creek and the shore of the lake there is a cluster of hills cut by numerous ravines, especially towards the north, where they assume crater-like forms, and to a casual observer might appear to be the remains of old volcanic craters. The hills rise from 80 to a 100 feet or more above the level of the lake, and are well wooded. The hollows are occupied by mud springs, sulphur pools, and steam vents, which seemed to be in the last stages of action, although this appearance may be due to the lack of water in abundance. The rocks of the hills are conglomerates and sandstones, made up of particles of obsidian or pitchstone and geyserite pebbles. In places the sandstones had a vitrified appearance, due in all probability, as Professor Bradley has suggested,* to the slow percolation of the spring waters through the sand while it was beneath the surface of the lake at points other than those of most active ebullition.

Toward the south the hills are more plateau-like, and the springs and vents are found in the gulches leading towards the lake shore. North of the groups shown on the map there are gulches with vents and unimportant springs not shown on the accompanying map, but indicated on the map in the report for 1872, which is on a smaller scale, and includes more of the surrounding country.

The rocks in the hills and hollows are reddish in hue, looking as though they had been subjected to the action of fire. This is due to their disintegration and the oxidation of the contained iron. This disintegration is due partly to the action of the springs and partly to atmospheric influences. Professor Bradley, in the report for 1872, speaking of the hollows, says: "It becomes evident that they have been hollowed out of the surrounding sandstone by the action of the hot springs themselves, which have disintegrated and removed portions of the standstone and conglomerate of the old lake-terrace. Worn bits of rock, penetrated by numerous small irregular holes, are abundant on all the lower parts of the slopes, as well as about the existing vents, showing that the process is still going on."

In cataloguing the springs found in the Sulphur Hills, I have divided them into two groups, viz, Sulphur Hills Group and the Shore Group.

The Sulphur Hills Group is separated from the Little Giant Group by three hills, 40 to 50 feet high, and occupies a basin of about the same level as the Little Giant Group. The springs are mainly turbid alum springs and mud holes, which are evidently affected by the state of water supply. Many that were mere steam vents when examined by us, must be boiling and sputtering pools when they are supplied with water.

On the side of the hill north of the main part of the group there are sulphur-lined steam vents, and on breaking the crust beautiful crystals are found. The Shore Group includes the springs that are found along the edge of the lake. These are really divisible into two subgroups, but none of the springs are at all important.

North of the springs numbered in the group are two small gulches, with steam vents and sulphur holes at their heads. The location of the springs will be rendered clear by a reference to the map.

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* Report U. S. Geological Survey, 1872, p. 247.

Table of the Sulphur Hills Group.

Number.	Size.	Depth.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
			° F.		° F.	
1	Space covered by the springs is 5 by 12½ feet.		*a* 108 *b* 130 *c* 190 *d* 169	10.30 a. m.	69	These are alum springs in blue mud; *d* is reddish in color; *c* has 5 centers of ebullition. There are a number of steam vents among the springs.
2	7 by 11 feet		100		69	Yellowish turbid pool, with a large number of bubbling vents around it.
3	15 by 17 feet		85		69	Turbid pool; water has alum taste; there are vents near by.
4	9 by 17 feet		160		69	Spring, with semi-clear water, actively bubbling, especially at one end; there is considerable overflow from it.
5	7 by 8 feet		136		69	Turbid alum spring.
6						Several sand bubbles; nearly dry.
7		3 to 4 inches.	120		69	Clear, with yellow bottom.
8	*a* and *b* are 6 by 4 inches.		*a* 175 *b* 195		69	*a* and *b* are small sulphur vents.
9	*d*, *e*, *f*, and *g* are about 6 by 3 inches.		*c* 195 *d* 182 *e* 180 *f* 182 *g* 145 *h* 183 *i* 173 *k* 131 *o* 122			*c* contains about 12 sputter holes in clear geyserite. *d*, *e*, *f*, and *g* are turbid boilers.
10						This marks a collection of semi-turbid springs.
11						A collection of mud holes, back of which are steam sulphur vents.
12						Is a sulphur steam vent.
13						Steam vent.

Table of the Shore Group.

Number.	Size.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
		° F.		° F.	
1		194	1.05 p. m.	70	Two rusty-colored hard geyserite basins, with water sputtering at irregular intervals. They are on the shore of the lake.
2	*a*, 3 by 3 feet *b*, 1 by 1 foot	*a* 190 *b* 190			Besides the two principal springs *a* and *b*, there are four or five holes or vents; *a* is lined with hard geyserite.
3		*a* 165 *b* 145			These springs form one group, and the steam flowing from them heads in No. 3, receiving water from the others, except 7, as it passes between them. There is considerable overflow. The springs are not far from the lake.
4	Vents, 4 by 4 inches	*a* 175 *b* 180 *c* 185			Sulphur-lined vents.
5	2 by 2 feet	96	12 m.	69	
6		115			
7				70	Slimy sulphur oozes.
8		194	2.10 p. m.	70	There are at this place a number of steam vents, some of which are in the lake.
9	8 by 10 feet	140			Muddy pool.
10					Steam vents.
11	52 by 46 feet	85			Green pool, with surrounding springs.
12		121			
13	9½ by 10 feet	86			Mud pool near 11.

These springs are on the shore of the lake, above Point Lookout and in the gulches, leading to the lake.

LAKE GROUP.

Under the designation of Lake Group I have included a group of sputtering springs and holes that lie mainly on a sand flat at the mouth of the small streams, or courses, that carry the drainage from the Orion Group when there is a surplus of water in wet seasons. It is evident that at times these springs are under water, and at the time we saw them we noticed springs bubbling through the water of the lake, not far from the shore. I have included with them a mud pot that is on higher ground, and also two pools (Nos. 14, 15, 16, and 17) that might have been included with the Orion Group, as they are but little lower than the plateau of the latter. They were visited, however, when the springs on the sand flat were noted. The latter are on the north edge of the swampy meadows that border on the lake south of Point Lookout. It is through this swamp that Shoshone Creek meanders to flow into the lake. There are a number of springs scattered over it, as was evident each morning when the air was cool enough to make the rising steam visible. The lake shore must change from year to year, as we found it very different from what was observed in 1872.

Table of the Lake Group.

No.	Size.	Depth.	Surface temperature.	Temperature of air.	Remarks.
			° *F.*	° *F.*	
1	.....	.....	.....	....	Mound surrounded by spitting holes.
2	5 by 6½ feet	*a*, 3½ feet....	154	70	This spring has a basin and an irregular opening, and has a scalloped rim. Sulphur lines the outlet and water-way. The water flows out gently, bubbles of sulphuretted hydrogen gas escape gently.
	.....	*b*, 4½ feet....	.....	....	
3	*a*, 3 by 2 feet.....	.....	105	....	There are two openings in one spring; *a* is red-lined, *b* is gray-lined with 12 bubbling holes.
	b, 3 feet diameter .	.....	108	....	
4	.....	.....	.....	....	Small sulphur cone.
5	*a*, 30 by 36 inches .	.....	Not taken.	....	There are 5 or 6 holes in connection with these and a number of steam vents.
	b, 35 by 17 inches .	.....	142	....	
6	32 by 18 inches....	.....	159	....	This is a quiet pool.
7	*a*, 26 by 56 inches .	.....	124	....	These springs form a group in which there are numerous sputtering holes.
	b, 12 by 12 feet....	.....	124	....	
	c, 5 by 5 feet	.....	85	....	
	d, 12 by 14 inches .	.....	125	....	
	e, 14 by 17 inches .	.....	130	....	
8	.....	.....	Too low for temperature.	..	Four or five sulphur-lined vents.
9	12 by 13 inches....	1 foot	181	....	Small bulging spring lined with grey geyserite.
10	36 by 40 inches....	.....	177	....	
11	*a*, 1 inch diameter	.....	Not taken ..	....	Three small sulphur-lined mounds. In *b* and *c* the water rises and falls and spouts a few inches.
	b, 6 by 9 inches ..	.....	192	....	
	c, 5 by 12 inches...	.....	195	....	
12	5 by 7 inches.....	.....	130	....	This spring has a mound 3 feet in diameter.
13	8½ by 9½ feet.....	.....	Not taken ..	....	Blue mud caldron.
14	}		155	....	Small sulphur ooze near No. 13.
15	} 127 by 786 feet ...	.....	Cold	....	Large pool divided by constrictions into three.
16	}			...	
17	20 by 22 by 25 feet.	465 feet	119	....	Large pool with red leathery lining, no outlet, slight bubbling in the center.

WESTERN GROUP.

The groups hitherto described are on the east side of the creek. Those on the west side are equally important as springs, although the geysers are all small, none equaling the Union Geyser, nor even the the Minute Man and Little Giant. Professor Bradley was of the opinion that the geysers on the west side were all young. However that may be, none of the mounds are of much height or extent compared with those on the east side. Opposite our camp is the mouth of a creek, named Quick Run by the party in 1872, but on the accompanying map is called Fall Creek. Springs extend some distance up the valley of this small stream, and remains are found on the sides of the hills. This was called the Western Geyser Division on the map of 1872, and I have retained the name western for the group, although there is probably no true geyser. It is the most western of all the groups in the Shoshone Basin, and contains some large boiling springs. The basin in which the springs occur is on the north side of the creek, mainly on small branches, there being very few on the main stream, which, above the point where Fall Creek joins it, is a cold stream with good drinking water.

Table of the Western Group, or Division.

No.	Name.	Size of spring.	Surface temperature.	Deep temperatures.	Temperature of air.	Time of observation.	Remarks.
			°F.		°F.		
1		24 by 27½ feet, 4 inches to 2½ feet in depth.	172		67	9.30 a. m.	This spring has a large white pool-like basin, with a scalloped white rim. The basin is shallow, and receives water from No. 3. There is a red lined outlet. There are a half-dozen centers of ebullition and a sputtering hole back of the spring.
2		*a*, 3 by 3½ feet *b*, 15 by 18 inches	*a* 155 *b* 133		67		Two small dirty mud holes with floating scum.
3		Irregular pear-shaped basin.	169		67	9.45 a. m.	Brown-lined pool with a rim 6 to 8 inches high on one side. The pool is 4 to 6 inches deep, with hole 5 feet deep in center. There are three centers of gentle ebullition; overflow is to No. 1.
4	Red Spring	16 inches deep	168		67	9.50 a. m.	Beautiful red basin on a mound about 5 feet higher than No. 3, with two white-lined tubes, in which there is slight bubbling; no overflow at time of observation.
5		2 feet deep					Hole in grass.
6		3 feet by 18 inches	155		68		Muddy water pool in grass; sputters slightly.
7		3 feet diameter	120				Dead pool in grass. Near 5, 6, and 7 are other holes partly concealed in grass.
8	Boiling Caldron	10½ by 17 feet; pool, 5 to 6 feet deep.	Pool, 199 Spouter, 201	At bottom of pool, 6 feet below surface, 202.	73		Very active spring, constantly agitated whenever observed, beautiful blue-tinted water, two centers of ebullition.
9	Boiling Caldron	11 by 24 feet	200 201 201¼		73		Really a part of No. 8, from which it is separated by a narrow strip of deposit.
10		7 feet 3 inches by 18 inches.	198		73		Small gray geyserite pool, with two openings or holes, the largest 2 feet 9 inches by 1 foot 6 inches.
11		8 by 8 feet 8 inches, 3½ feet deep.	170	At bottom, 170	73		A beautiful spring with a gray-white basin, sloping to the center. The spring is bordered by a white line and bubbles slightly.
12		2 feet 3 inches by 2 feet 3 inches; 10 feet deep to tube.	149	9 feet down, 157	73		A white-bordered spring.
13		6 by 14 inches	Not taken				A beautiful white spring in the water-way from No. 9. The outlet is lined with red and yellow.
14		19 by 20 feet, basin 3 feet deep.	117		75		Quiet red-lined basin, with central basin; receives water from No. 9, through a yellow water-way.
15		6 feet 4 inches, by 7½ feet.	106		75		Red-lined pool, or dead spring, on a geyserite mound.
16		16½ by 20 feet	160		75		Yellowish-green tinted water in pool that overflows to No. 17.

Table of the Western Group, or Division—Continued.

No.	Name.	Size of spring.	Surface temperature.	Deep temperatures.	Temperture of air.	Time of observation.	Remarks.
17	Great Crater	40 by 45 feet, 20 feet deep.	162–165 At bubbler on edge, 195.		75		Deep crater in which the water is 6 to 8 feet below the top; receives overflow from No. 16 and No. 18.
18	Cream Spring	13 by 28 feet, 4½ feet deep.	160		75		White-lined with scalloped border. There are several centers of slight bubbling.
19		25 by 30 inches	196				Geyserite bubbler on a small mound, with red deposit lining outlet.
20			*a*, 92 *b*, 95 *c*, 158 *d*, 144 *e*, 150 *f*, 176				Collection of small muddy pools of irregular sizes and shapes. Only the principal temperatures are given.
21		7½ by 3 feet 10 inches.	185 190		75		Pool lined with fragments of geyserite in which the water is 3 feet below the surface.
22		*a*, 15 by 22 inches. *b*, 8 by 15 inches.	*a*, 123 *b*, 114				Small springs almost dead near the outlet from No. 17.
23		*a*, 19 feet diameter. *b*, small hole	*a*, 144 *b*, 104				Stagnant pool with surrounding mudholes.
24, 25		Collection of mudholes in grass.	Cool or cold				Pink, muddy, and clear stagnant holes in the grass.
26		9½ by 10 feet					Dead pool.
27		*a*, 26 feet diameter. *b*, not taken	*a*, 80 *b*, 75				Old basins almost empty.
28		15½ by 40 feet	Cold				Old basin with pinkish deposit.
29	Moss Basin	35 by 44 feet 9 inches.	163		75		Red-lined basin with moss-lined hole 3 by 5 feet at one end.
30							Small hole.
31		*a*, 3 by 3 feet *b*, 11 by 11 feet	*a*, 185 *b*, 152				*b* is a light red and white basin with a flat rim; *a*, a small gray quiet spring.
32		4 feet diameter					White mud pot.
33	Boiling Spring	32 by 36½ feet	189				Large blue boiling spring with strong overflow.
34		30 feet long					Dead pool.
35	Steam Vent	6 by 7 feet	198		75		Spring with steam vent above.
36	Mud Pots	2 by 3 feet					Small mud pots.
37		24½ by 34½ feet, 9½ feet deep	185	8 feet below, 188			Really two beautiful blue springs separated by a narrow ridge of deposit.
38	Nursery Springs	*a*, 5 feet diameter. *b*, 1 foot diameter. *c*, *d*, 9 by 8 feet	*a*, 155 *b*, 197 *c*, 170 *b*, 187				*a* is a flat spring; *c* is deep and is in basin with *b*; all these springs sputter.

39	.....	6 or 8 feet deep.....	112	.....	.....	Dark pool with red edge; slight bubbling.
40	.....	.....	Too deep.....	.....	.....	Hole in geyserite mound.
41	Muddy Pool	32 by 36 by 38 feet.	87	.....	.....	Large pool of muddy water; near by is a second one, a red pool, measuring $25\frac{1}{2}$ feet by 40 feet.
42	Red Pool	$10\frac{1}{2}$ by $38\frac{1}{2}$ feet	117	.....	.....	Red pool of water.
43	Black Pool.....	15 by 30 feet, 12 feet 3 inches deep.	120	.....	.....	Black pool almost hidin the grass; bubbles at one end.

DESCRIPTION.

The Western Group occupies an area of about 200 yards by 300 yards. The first springs met with are about 900 feet from the mouth of the creek, from which they are distant about 500 feet, at the foot of a hill, on the side of which there are mudholes and old steam vents. These springs, Nos. 1 to 7, form a subgroup, which needs no further description than has been given in the catalogue just presented. The drainage from the springs flows directly south to the creek over a gently sloping, area of geyserite, joining the drainage from No. 43, which is further east, and that from the subgroup next to be described, which is the one in which No. 8 is the principal spring. This subgroup is on a higher level than the one just described, and a strong stream of warm water proceeds from it, flowing in a brilliantly-colored water-way, which has a vigorous growth of confervoids. The springs worthy of particular mention are the Boiling Caldron, the Great Crater, and the Cream Spring.

The *Boiling Caldron* (Nos. 8 and 9) is composed of two basins separated by a very narrow strip of yellowish geyserite. No. 8 is the principal spring. It is an almost rectangular basin 10½ by 17 feet. At the south end of the spring is a black shelf of deposit, and on the west side a small yellow mound, in which the water is boiling vigorously, and from which huge volumes of steam escape. This escape of steam seems to be much greater in the evening, and about 6 p. m. each day we noticed from camp a large column ascending. The water spouts from 3 to 5 feet during the escape of the steam, which has periods of greater violence followed by lulls. The water in the pool has a greenish-blue tint, and there are two centers of ebullition. The temperature on the spouter was 201° F., and in the pool 199° F. at the surface and 202° F. at the bottom. No. 9 is longer than No. 8, measuring 24 feet, but is only from 11 to 15 feet in width. Water connects from one to the other. It has a yellowish-white basin, which appears to be simply a sort of crust over a deep basin. The holes broken through it are black, and number 9 or 10. There are three important ones that are strong spouters, being in action whenever observed; the temperatures were 200°, 201°, and 201¼. The water-way leading from the Caldron is beautiful, lined with white and orange colored cakes or plates of silica. The Boiling Caldron belongs to the class of constantly agitated springs, although it has periods of increased activity alternating with those of less action.

The *Great Crater* (No. 17) occupies a crater-like depression, 6 to 8 feet below the general surface. The spring is approximately circular, measuring 40 by 45 feet. In the center is a basin 20 feet deep, in which the water has a deep-greenish tint; bordering the basin is a yellow shelf-like projection; near the outlet is an opening through this shelf, where the temperature is 162° F., while in the main basin it is 165° F. The central basin steams slightly, and occasionally a few bubbles rise to the surface, but generally the spring is quiet. At one side there is a bubbler, in which the temperature is 190° F. A strong stream flows out from the spring through a yellow-lined water-way which descends to the creek level. The overflow of No. 18 finds its way into the crater, and whenever there is any overflow from No. 16, it pours into it also.

Cream Spring (No. 18).—This is a beautiful creamy-white basin with a fine scalloped border 3 or 4 inches in height. The center of the spring has a bluish tint, and there are three or four centers of slight bubbling. The total length of the spring is 28 feet, but one end is a shallow red lined basin, the main spring being 19½ feet by about 13, the shape being oval. The temperature is 160°, and the spring belongs to the class of quiet springs.

MAP OF THE

SHOSHONE GEYSER BASIN

WEST END OF SHOSHONE LAKE

YELLOWSTONE NATIONAL PARK

SURVEYED BY HENRY GANNETT AND

From notes and sketches by

J. E. McBRIDE

1878

Scale of Feet

The remaining springs of the subgroup are sufficiently described in the table. West of the subgroup is a collection of mud springs, and north of them another subgroup, consisting mainly of large, quiet, and comparatively cold pools.

No. 37 deserves particular mention, as it is one of the handsomest springs in the group. The water in them—for there are two basins—is of an exquisite blue tint. The two basins are separated by a ridge of geyserite over which the water flows. The largest basin measures 24½ by 17½ feet, but has a long arm of 27 feet. The smaller basin is 10 by 16½ feet.

The *Nursery Springs* are several small springs and sputter-holes. The drainage from this subgroup flows to the north of the group of No. 8. Westward is an open valley extending to the hills. On the south side are two springs, the water from which joins the drainage from the Nursery Springs, viz, Nos. 34 and 35. No. 34 is a dead pool with a green, and red basin 30 feet long. No. 35 consists of a steam vent and a spring. The spring is 6 by 7 feet at the foot of the hill, and pulsates regularly in sympathy with the steam vent. It is 6 inches deep, and has a temperature of 198°. Beautiful rosette-like masses line the outlet. The steam vent is on the side of the hill, 5 or 6 feet above the spring in red muddy deposit. The steam escapes in regular puffs, the intervals being about half a minute in length.

The only other springs in this group remaining to be described are the *Moss Basin* (No. 29), and the *Boiling Spring* No. 33. The first (No. 29) is at the head of a subgroup that is almost extinct. It is a red-lined basin 44 by 35 feet. This red lined basin is about 4 inches deep, and at one end is the deeper Moss Basin, back of which is a small circular spring having a temperature of 163° F.

No. 33 is a large blue-tinted boiling spring in a gulch tributary to Fall Creek; it is 32 by 36½ feet, and has a deep basin in the center. There are two points of strong overflow; the water flows to the creek over a brilliantly colored outlet, yellow being the principal color; which contrasts with the sky-blue tint of the spring. The hills around this gulch are timbered, and back of them are the remnants of several extinct springs. Among them are also some dry mud pots, which in wet weather may become active mud springs, judging from their present appearance.

Black Pool No. 43 is detached from the rest of the group lying near the springs of the south group, but, as its drainage is to the southward, it has been included with the Western Group.

ISLAND GROUP.

The Island Group is so named from its being opposite islands in the river, and also from the fact of its being isolated. All the springs are small and comparatively unimportant.

Table of Island Group.

No.	Size.	Depth.	Surface temperature.	Time of observation.	Temperature of air.	Remarks.
			°F.		°F.	
1	Space covered 13 feet long.	.....	186	3 p. m.	75	These are five openings in crust rather than separate springs. Water comes from No. 3.
2	3 by 4½ feet	.....	182	.....	....	There are three small openings near by.
3	11 by 21 feet	6 to 10 feet..	*190 †190 ‡192	.....	75	Light greenish pool, bubbling in four or five places.
4	6 by 6½ feet	3 feet	158	.....	75	The water, which is about a foot below the surface, is generally quiet, only a few bubbles.
5	11 by 11½ feet	3½ feet	117	... .	75	A red-lined pool from which bubbles occasionally escape.
6	Depression, 11½ feet by 14 feet 8 inches: *a*, 2 feet by 1½ feet; *b*, 10 by 20 inches	.....	*a*, 155 *b*, 183	.....	75	A depression in which there are two quiet muddy pools, with soapy-looking water. At one end of the depression is a steam vent.
7	9½ by 6½ feet outside basin. Principal openings: *a*, 1½ by 2½ feet; *b*, 2½ by 3¼ feet.	.....	*a*, 195 *b*, 199	.....	75	There are five vents or openings, all continual spouters. Around the edges of the spring is a dark geyserite border with a yellow waterway.
8	*a b c*, three small cones; basin of *c* measures 4 by 5 feet.	.....	*c*, 197 *b*, 198	.....	75	The orifices are 1 to 2 inches, cone 6 inches, diameter; basin of *c* shows evidence of spouting. There are two outlets to the river.
9	Basin 9 feet 9 inches by 15 feet 8 inches. Principal openings: *a*, 11 by 17 inches; *b*, 4 feet 10 by 6 inches; *c*, 3 feet by 2 feet 8 inches.	.....	*a*, 197 *b*, 197 *c*, 199	.....	....	About six openings or vents in basin. Between *a* and *c* there are two constant spouters throwing water 6 inches to 2 feet in jets. *a* is quiet; *c* has a raised beaded crater, reddish-brown lined, with one center of ebullition spouting constantly.
10	4 feet by 5 feet.....	.....	80	.....	....	Green-scum pool with three basins.

* Surface. † Six feet below. ‡ Eight feet below.

SOUTH GROUP.

Following up Shoshone Creek on the west side from the Island Group, we soon ascend a mound or terrace of siliceous deposit, which rises 25 to 30 feet above the creek level. The springs on this mound or terrace, which extends some distance up the creek, I have divided into two groups, as the drainage from the springs naturally so divides them. The South Base Group is the one first met with, and includes fifteen springs, all but one of them being situated near the base of the hills at the upper margin of the mound.

On the map published in the report for 1872 only seven or eight of the springs of this group are indicated, and in Professor Bradley's report only one of them is particularly referred to, as follows:

> Nearer the base of the hills there are several large hot pools. One of them was so well furnished with coralliform masses, standing in the shallow water near its edge, as to be called the Coral Pool. This measured about 40 by 50 feet, with a shallow border, and a deep central pit about 10 feet across, from which numerous bubbles of gas were escaping. There is a strong flow of water of the temperature of 160°.

This spring was easily recognized and the name has been retained.

The following table gives the condensed description of the springs of the group:

CORAL SPRING. SHOSHONE BASIN.

Table of the South Group.

No.	Name.	Size of spring.	Surface temperature.	Deep temperatures.	Temperature of air.	Remarks.
			°F.	°F.	°F.	
1	.....	3 feet 3 inches by 7 feet 3 inches; over 10 feet deep.	190	9 feet below, 194	59	White and lead colored basin, with light yellow water-way leading to the river. The overflow from No. 9 flows into the spring.
2	Coral Spring..	38½ by 55 feet; 12 feet 10 inches deep.	177	4 feet below, 178	60	A very handsome blue spring with an ornamental edge.
3,4	Three Crater Spring.	26½ by 26½ feet.....	151 160 179	.....	60	A large square pool with three spring openings. Receives water from No. 2.
5	.....	7 feet 3 inches wide..	148 165	.....	60	In water-way from Nos. 2 and 3.
6	.....	2 by 3 inches.....	140	.....		A small opening on the top of a geyserite mound back of the springs.
7	.....	3 by 4 feet 9 inches..	97	.....	60	Red pool.
8	.....	.....	177	.....	60	White pool, which sputters irregularly: 7 and 8 are both on the terraced water-way which extends from 3, 4, and 5 towards the river.
9	Wave Spring .	2½ feet diameter	171	.....	60	Receives overflow from 4 and 5, and when spouting throws the water into waves.
10	.....	8 by 9 feet; 3 feet deep.	199	2 feet below, 206	....	Spouts irregularly 2 to 4 feet.
11	Flake Spring .	17½ to 34 feet; 6 feet deep.	176	4 feet below, 188	....	Light-blue pool.
12 and 13	Blue Glass Spring.	12 by 39 feet.....	168*a* to 196*b*	7 feet below, 198½ 8 feet below, 199½	....	Double spring, with beautiful blue cavern at one end and white basin at the other.
14	.....	5 by 9 feet; 4½ feet deep.	197	3 feet below, 201	60	Bubbles and spurts from one foot to two feet.
15	.....	21 by 9 inches.....	158	.....	....	A small pool on the edge of the river on a mound of geyserite.

DESCRIPTION.

No. 2. *Coral Spring* (Plate XXXIII).—This is perhaps the principal spring of the group, and it is certainly one of the handsomest in the Shoshone Basin. The basin of the spring in its greatest length is 55 feet, and in width measures 38½ feet. This basin is shallow and light yellow in color with gray and orange tinted shallow pools just outside the ornamented edge. In the center is a pit or bowl about 15 feet in diameter and 12 feet deep. In this the water is of a sky-blue tint, contrasting most beautifully with the color of the surrounding basin. The edge or rim is handsomely ornamented with coral-like and rosette masses, which also border the lemon-yellow-colored outlet. Gray, yellow, and blue are the colors presented in this spring. The temperature in the center was 177° at the surface, and 178° four feet below. The surface of the spring steams slightly, but was quiet when examined. It probably belongs to the class of quiet pools.

At one side of the spring limbs of trees were found which had evidently been soaked in the water for a considerable time. They were

coated with a hard sugary-looking coating of silica, beneath which the fiber of the wood had been converted into a pure white pulp resembling the pulp seen in paper-mills. The water from the Coral Spring pours into the next one, No. 3.

Nos. 3 and 4. *Three Crater Spring.*—This is an expansion of the water-way from the Coral Spring, and in the shallow basin thus formed there are three principal spring openings, besides three or four miner ones. The basin is almost square at the corners and measures 26½ by 26½ feet. It is greenish yellow in color and the spring openings are white. The temperatures in the latter are 160° F. in the opening nearest the base of the hill and the outlets, 151° F. in the central orifice, and 179° F. in the one to the left, which has a scalloped border. There are two main outlets; the one nearest the hills passes to the left of spring No. 5, and spreads out on the terraces at springs No. 7 and No. 8. This is lemon yellow in color, while the other is deep red, and passes to the right of No. 5, and gradually spreads out on the terraces, turning to the right. These terraces are composed of shallow basins with crenulated edges. They are stained red and gray, and reach almost to the edge of the river from springs 5, 7, and 8.

No. 5. In the table there are two temperatures given. The first one (148° F.) is the temperature of the spring, while the other (165° F.) is the temperature in a hole just back of it, near the right-hand water outlet of No. 3.

Nos. 6, 7, and 8 do not deserve special mention.

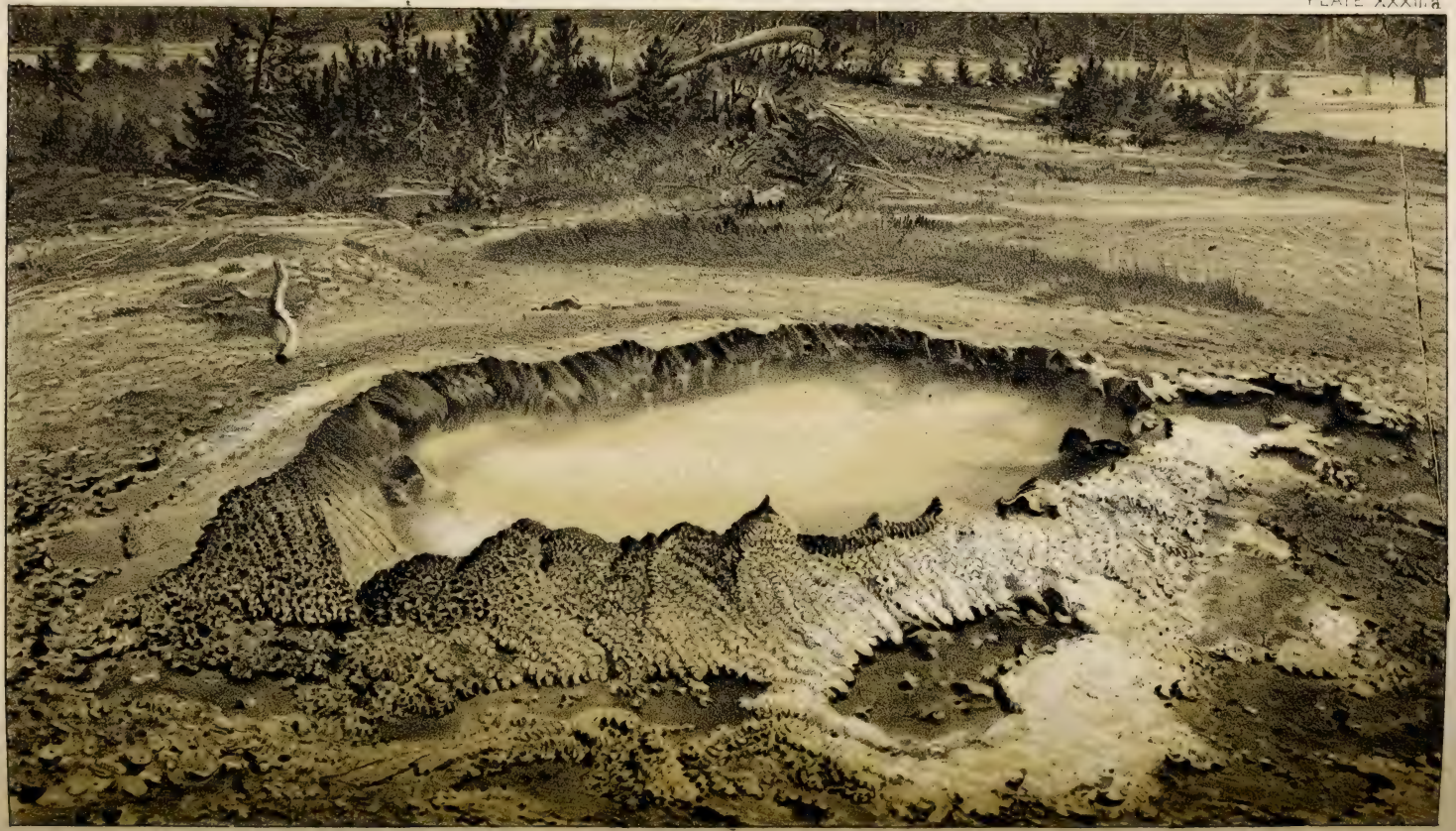
No. 9. *Wave Spring.*—This is a small circular pool with a creamy white basin. It receives water from Nos. 3 and 5 and pulsates with occasional spurts of water. No. 1. is on the water-way leading from No. 9.

No. 10. In the center of a yellow basin measuring 8 by 9 feet is a gray hole 2 feet diameter and 3 feet deep, from which the water spouts irregularly to the height of 3 or 4 feet; the surface temperature is 199° F., and at 2 feet below the surface it is 206°. The outlet is beautifully colored with red and yellow, which grows less vivid as it recedes from the spring.

No. 11. *Flake Spring* was named from the flaky masses of broken deposit seen at the upper end of the spring; a light blue pool is at one side of the basin.

Nos. 12 and 13. *Blue Glass Spring.*—This spring was named from the color of the water in the deep pool at one end of it. The entire basin measures 39 by 12 feet. At the lower end is a circular white hole 5½ by 6 feet, which is the upper end of a white velvety-coated funnel; it is nearly 9 feet deep, and a quiet spring, with a temperature of 168° F. at the surface and 198½° F. seven feet below. At the opposite end is a cavern-like spring, or pool, of a deep-blue color. It measures 12 by 8 feet, and is 9 or 10 feet deep. Its surface temperature is 196° F. and at 8 feet below it is 199½° F. It is quiet, and separated from the rest of the basin by a fringe of geyserite. From the latter to the spring first described there extends a shallow grey-white basin from 2 to 3 inches deptn. This basin extends around the funnel-shaped orifice. This spring probably belongs to the class of quiet springs, as there is no evidence of its being a geyser, nor did we ever see it even boiling.

No. 14 (Plate XXXIII *a*) in an oval spring 9 feet long by 5 feet wide and 4½ feet deep. It has a raised yellow beaded rim of 6 inches to a foot height, and is constantly agitated, spurting to a foot or two above the crater. The surface temperature is 197° F., and at 3 feet below the surface is 201° F. It is some distance back of No. 12, to which the overflow pours over a terraced water-way.



SPRING N° 14 SOUTH GROUP SHOSHONE BASIN

NORTH GROUP.

The springs included under this group are situated on the continuation of the mound on which the South Group is located. Towards the north it slopes gradually to the level of the Yellow Crater Group. The slopes towards the river are not so steep as in the south portion of the mound, and a number of the springs are near the river-level. There are some 47 springs included in the table, of which only a few are given on the map in the report for 1872. Professor Bradley, in the report, simply mentions the group, as follows:

On the opposite [west] side of the creek is a broad terrace of the siliceous spring deposits, upon which stand several small mounds very prettily ornamented, from 1 foot to 2 feet high, whose pools boil considerably, and evidently spout occasionally, though no one of them was seen in eruption. One of these, near the creek and nearly opposite to Minute-Man, is shaped like a conch-shell and strongly colored with iron, and was called Iron Conch Geyser.

The spring mentioned by Professor Bradley could not be identified, as none of those near the river, opposite the Minute-Man, answer the description. The Bronze Geyser is strongly colored with iron, but the shape does not agree. In the following table all the springs of the group are noted:

Table of the North Group.

No.	Name.	Size of spring.	Surface temperature.	Deep temperature.	Temperature of air.	Remarks.
			°F.	°F.	°F.	
1	.....	*a* 2 by 3 feet	*a* 198	.....	70	*a* is a constant spouter.
		b 7 by 10 feet.....	*b* 189	.....	....	*b* has a raised beaded rim, yellow and white. There are 5 other openings.
2	Fissure Spring	Fissure 3 feet 9 inches by 1 foot.	191½	.....	70	There are 3 holes besides the main fissure.
3	.....	9 by 6 feet; 5 feet deep.	162	3 feet below, 167	70	White-lined pool, with yellow-lined waterway.
4	.....	8½ feet diameter; 6 feet deep.	190	4 feet below, 199	70	Almost circular white-lined pool, with scalloped edge. It is a gentle boiler.
5	.....	20 by 30 inches.	140	.....	70	Small red and green moss-lined pool, near a dead mound. Slight bubbling noted.
6	Glen Spring...	45½ by 20 or 30 feet; 6 feet deep at deepest.	160	.....	70	Irregular in shape, with water rising and falling. One of the handsomest springs in the region.
7	*b* Brown Sponge	*a* 7 by 10½ feet	*a* 189	*a* 9 feet below, 197	70	*a* is a yellow pool.
		b 4½ by 5 feet; 2½ feet deep.	*b* 181	*b* ½ foot below, 190	....	*b* is lined with brown globular masses, and the water has periodic risings and fallings.
8	Yellow Sponge	8 by 14 feet outside.	*189 and 196	.....	70	Spouts several feet above the crater, which is light yellow. The water splashes irregularly.
9	.....	Fissure 7 feet 6 inches long.	.....	.....	....	Between 8 and 9 are two holes, one of which is a geyser vent. Below 9 is a third hole.
10	.....	4 openings in space of 2 by 4 feet.	*c* 185	.....	70	*a* is a small spouter, throwing water 6 inches to a foot; *c* is 3 by 5 feet.

* During eruption it is 199.

Table of the North Group—Continued.

No.	Name.	Size of spring.	Surface temperature.	Deep temperature.	Temperature of air.	Remarks.
			°F.	°F.	°F.	
11	Velvet Spring	11 by 19 feet; 8 feet deep.	198	6 feet below, 198	70	Beautiful white-lined spring, with pool-like basin at one end. Spouts and boils at the spring end.
12	.....	*a* 9 by 20 feet.....	*a* 193	.....	70	*a* has basin at one end and spring at other.
		b 4 by 7 feet; 8 feet deep.	*b* 193	.....	....	*b* is a white-lined pool, somewhat irregular in shape.
13	Geyser.....	*a* 8½ feet diameter; 8 to 9 feet deep. *b* 20½ by 16 feet.	*a* 193 *b* 188 to 194	....	70	*b* is a geyser; spouts from 4 to 20 feet.
14	.....	*a* 7 feet by 1 foot 9 inches.	*a* 198½	.....	70	Two small holes beside, near 45.
15	.....	4½ by 6 feet	*192	2½ below surface, 196.	70	A geyser throwing water a foot or two.
16	.....	7 by 3 feet	*a* 178½ *b* 178	.....	70	Two circular gray and white pools, separated by flakes of geyserite, each about 3 or 3½ feet diameter.
17	*b* Bronze Geyser.	*a* 5 by 6½ feet.....	*a* 190	.....	70	*a* is beautiful gold-lined spring.
		b 5½ feet long.....	.....	*b* 2 feet down, 197	....	*b* is a geyser with bronze ornamentation; *d* is a sputtering cone.
		c 2 by 2 feet	.....	.....	....	*c* is clear spring.
18	.....	3 feet by 3 feet 10 inches.	157	.....	60	Oval quiet spring.
19	.....	.....	.....	.....	....	
20	.....	5 by 7 feet	200	.....	....	Several openings in basin; the principal one is a black spouter.
21	Lion Geyser...	17 by 17 feet	186	.....	60	There are two openings, separated by flaky deposit; openings are about 2 feet diameter.
22	.....	4 by 5 feet	137	.....	60	Quiet, green and red lined pool.
23	.....	2 feet 9 inches by 18 inches	198	.....	60	Two springs are on each side of 23; one is 2 feet by 2 feet 10 inches, the other 4½ by 5 feet.
24	.....	6½ by 8 feet; 3 feet deep.	187	.....	60	White, bubbling basin, in which the water is 2½ feet below the top.
25	.....	6 by 2½ feet; 2½ feet deep.	181	.....	60	White-lined hole.
26	.....	Space 3 feet wide ...	186	.....	66	A number of small holes near the river.
27	.....	1 foot 10 inches by 3 inches.	199	.....	66	Fissure-like spring.
28	.....	4 by 6 feet	199	6 feet below, 200	66	White cavern-like spring, boiling and bubbling.
29	.....	3½ feet diameter; 8 inches deep.	199	.....	....	Beaded bubbler.
30	.....	10 by 15 feet	164	.....	....	Receives water from group about No. 20.
31	.....	5½ by 10½ feet	193	.....	....	Gray basin, with globular masses lining it.
32	Frill Spring...	5 by 7 feet; 9 feet deep.	192	7½ feet below, 199	66	White basin, with frill edge. Sends water to 33.
33	Pearl Spring ..	5 feet 3 inches by 7½ feet.	185	18 inches below, 187.	66	Beautiful white, pearly basin. Red-lined outlet; receives overflow from 32.
34	.....	2 feet by 2 inches ...	197	.....	....	Probably an underground connection with No. 33.
35	.....	2 by 5 feet	195	.....	....	Bulging spring.

*Near eruption, 199.

CRATER OF BROWN SPONGE SPRING

Table of the North Group—Continued.

No.	Name.	Size of spring.	Surface temperature.	Deep temperature.	Temperature of air.	Remarks.
			° F.	° F.	° F.	
36		*a* 2½ by 4½ feet *b* 6 by 6½ feet.	*a* 188 *b* 190			Two gray pools, about a foot deep each.
37	Grotto Spring	5 by 6 feet	192	4 feet below, 201		White scalloped basin, with yellow waterway.
37½		3 by 5 feet				Dead pool.
38		3 feet 4 inches by 3½ feet.	192			Quiet, gray pool, with water 2 feet below top. Bubbles a little at times.
39		Openings cover 21 by 11½ feet.				Four openings, one evidently the crater of an old geyser.
40		11 by 14 feet; 2½ feet deep.	199			Pool almost played out. Sputters at one point.
41		*a* 4½ feet diameter *b* 9 by 9 feet	195 195			*a* is yellow-lined. *b* is white-lined.
42	Funnel Spring	*a* 4 by 12 feet	*a* 199½			*a* is a yellow-lined violent bubbler.
		b 10 by 15 feet	*b* 193	*b* 8 feet down, 199		*b* is a light-blue spring. Steam escapes in volumes.
43		6½ by 8 feet	135			Dirty-yellow pool.
44		7 by 9 feet	195			Near 41; white-lined.
45			*p* 208 *b* 209			Two sputter-holes near No. 14.
46		*a* 5 by 6½ feet *b* Small hole	*a* 168 *b* 168			There are a number of holes, nearly all dead. Principal temperature taken.
47	Mud Springs		197 200 140 135 161 135 106 122 184 164 187 157 182			Collection of mud pots and holes in grass.

DESCRIPTION.

No. 6. *Glen Spring.*—This, which is the largest spring of the group, is the one marked Big Hot Basin on the map of 1872. It is a beautiful green basin 45½ feet long, situated in a gulch at the foot of the hills some distance back of the other springs of the group. It is irregular in shape, but is about 20 to 30 feet wide. There is a central bowl, or basin, measuring 4 by 8 feet, which is 6 feet deep. From this center the water bulges at intervals which were not determined. On one of our visits the basin surrounding it was empty, and at another time it was bulging and the basin was full. It was at this time that the temperature of 160° F., given in the table, was obtained. When active there is a strong overflow, which flows from the spring in a beautiful deep-red trough-like outlet bordered with rosette-like masses of gray, brown, and white geyserite. The coloring in the basin of the spring is very handsome, delicate tints of gray, pink, and yellow being intermingled. The border around it is scalloped and ornamented with masses of deposit.

No. 7. *Brown Sponge* (Plate XXXIV).—This is the Brown Crater of Bechler's 1872 map, and is a peculiar opening in the surface. It is best

appreciated by reference to the illustration engraved from a photograph. There is no raised crater, but a hole bordered by dark-brown spongy-looking masses of siliceous sinter, or geyserite. They are irregularly globular in shape, and the outer edge is bordered with flaky masses like many of the springs. The orifice of the spring is 4½ by 5 feet, and 2½ feet deep. In this the water appears very dark, although really clear. It has a temperature of 181° F. at the surface and 190° at the depth of a foot and a half, and rises and falls at intervals not determined. It is a boiling spring, being in active ebullition whenever seen by us. The illustration shows it when the water has receded. Back of the crater is a yellow pool, *a* of No. 7 in the table given above. The springs present no evidence of any connection between them.

No. 8. *Yellow Sponge.*—This spring was named from the irregular yellow masses which line the inside of the basin. It is evidently not a true geyser, although the water spurts to the height of several feet above the top of the crater, or mound, in which it is. The latter is beautifully beaded, rising a few inches above the general level. The water rises and falls in the basin and is in constant agitation, splashing and spouting irregularly. The temperature in this basin was 196 when the water was low and 199 when it was spouting. The temperature, 189, given under No. 8 in the table, was taken in the opening immediately back of the Yellow Sponge, which is on the same mound. There are several openings which are smaller.

No. 11. *Velvet Spring* (Plate XXXV).—This is a very handsome rectangular spring with rounded edgesand a crenulated border, or rim, 6 inches high. The total length of the spring is 19 feet and the width about 11 feet. The spring has two portions. That in the front portion of the basin is a cavern-like hole 6½ by 11 feet, and 8 feet deep. The water in this appears of a beautiful light-blue tint and has a temperature of 198° F. both at the surface and 6 feet below. Back of this and occupying the remainder of the basin is a white, velvety platform, over which the water is only a few inches deep. Scattered over this platform are small, yellow, mushroom-like masses of geyserite which reach just above the surface of the water. In front of the spring are a number of small, shallow basins, and back is a terraced waterway which carries water from springs 2 and 3 to this one. When the temperatures given in the table were taken the spring was quiet, but it has periods of active boiling and spouting, although not a true geyser.

No. 13. *Bead Geyser.*—This geyser has a typical basin, which is 16 by 20½ feet, in the center of which there is an orifice measuring 1½ by 2 feet 4 inches. It was seen in eruption three times, throwing the water from 10 to 20 feet. The temperature when the water was rising was 188° F. At another time the temperature was 194° F., and when spouting it was 196° F. Surrounding the basin are the beaded, cauliflower-like deposits so typical of the true geyser basins, or bowls. Back of the geyser is a circular spring (*a* of table) 8½ feet diameter; temperature 193° F.

No. 15 (small geyser) is a geyser spring throwing water to the height of 2 to 5 feet at intervals of about 1 minute between the end and beginnings of spoutings, which last about 2 minutes each.

No. 17. *Bronze Geyser* (Plate XXXVI).—This is a handsome, deep, gold-yellow and reddish-yellow basin, with bronze ornamentation on the outside. There are two openings, one of which (*a*) is a fluctuating spring of a deep-yellow color in the interior of the basin; *b* is the spouter (shown to the right in the plate), and is more red in color. It spouts 2 or 3 feet when the basin is full. It is constantly agitated, and probably never throws a definite column of water. The spring is remarkable for the bronze color and luster of the surrounding ornamentation. This luster

VELVET SPRING SHOSHONE BASIN.

remains after the specimens are dry and have been kept for months. It is probably due to iron in the composition of the deposit. The springs are surrounded with nodular masses of it, the tops of which are bronzed. The main spring (*b*) is 5½ feet long and surrounded by small, shallow basins. Its temperature is 197 at about 2 feet below the surface. This spring is one of a subgroup which is near the level of the river.

No. 21. *Lion Geyser.*—This is a small spouter in a basin measuring 17 by 17 feet. The orifice of the spouter is about 2 feet in diameter. There is another opening of about the same size. The water is spurted diagonally to a considerable height from beneath a flaky deposit; the interval was not determined. On the 16th of August it spurted about half-past 12, the eruption lasting about 2 minutes. On the 25th it was noted three times as follows: 9 a. m., 9.40 a. m., 10.42 a. m; the intervals here being 40 minutes and 1 hour and 2 minutes. On the 26th two eruptions were noted as follows: 12.58 p. m., 1.29 p. m., showing an interval of 31 minutes. The observations, however, were insufficient to deduce any conclusions. Temperatures were 186° F. in geyser, 156° F. in outer opening.

No. 32. *Frill Spring.*—This was named from the white, frill like edge on the inner spring. The outer edge of the outer spring is yellow and gray, bordered with rosette-like masses which extend into the white-lined water outlet; surface temperature 192° F., 7½ feet below the surface; 199° F. Water goes to 33 from this spring.

No. 33. *Pearl Spring*, named from the white, pearly basin with rosette edge. A red-lined outlet carries away the surplus water. The spring is irregular in shape and has a surface temperature of 185, which increases to 187 at a depth of 18 inches below the surface.

YELLOW CRATER GROUP.

The Yellow Crater Group designates a small scattered group of springs that are located back of the marshy area on the west side of the creek, opposite the Little Giant Group. The spring from which we have named the group was so called on Mr. Bechler's Map of 1872.

No. 1. *Yellow Crater Spring* is a white, funnel-shaped basin with an orange-yellow rim, on the summit of a geyserite mound. Near it is a second mound, in which the spring is now extinct.

In the marshes below the springs enumerated in the table following this there are a number of spring holes concealed in the grass. The group as a whole is unimportant, containing no geysers, and the reader is referred to the table for particulars in regard to the springs included under it.

No 7 is probably the Boiling Pond of Bechler's 1872 map.

Table of the Yellow Crater Group.

No.	Size of spring.	Surface temperature.	Temperature of air.	Remarks.
		°F.		
1	6 feet diameter, 3½ feet deep.	154	72	White, funnel-shaped basin, with orange-yellow rim, on a geyserite mound.
2	40 by 56 inches	173	72	Brownish-gray pool
3	15 by 18 feet	150½	72	Yellow pool, red at one end, with holes in the bottom. There are sulphur oozes and mud holes in the grass below the sprins.
4	3 feet diameter	145	72	This is a yellow and reddish pool, with an active hole close by and several other small openings between it and No. 5.
	a 15 inches by 18 inches	*a* 163		
	b small hole	*b* 190		

Table of the Yellow Crater Group—Continued.

No.	Size of spring.	Surface temperature.	Temperature of air.	Remarks.
		°F.		
5	Small holes	186 162	72	The principal spring is a small geyser cone surrounded by a number of small pools.
6				
7	3½ by 4½ feet	Not taken	.....	Pearly and red geyserite.
9	83½ by 30 feet	Not taken	.....	Large red pool with springs at one end.
	4½ by 13 feet, 4 feet deep	190	.....	Plate-like yellow basin. Hole at one end spouts a little.
10	6 feet by 7½ feet	162 170 198	.....	There are 5 sputtering holes in a basin, and outside are two, *a* and *b*.
	a 1 foot diameter	*a* 170		
	b 1 foot diameter	*b* 195		
11	*a* 9 feet long	*a* 190	72	*a* is a fissure. Between 9 and 11 are other springs and vents; 11 has a red-lined outlet.
	b 3½ feet long	*b* 190		
13	*c* 2½ by 3½ feet	*c* 195		
14		.....	.....	Simply oozes in the marsh, where it is impossible to define springs.

RECAPITULATION.

The following is a recapitulation of the springs of the Shoshone Geyser Basin:

Group.	No. of springs.	Highest surface temperature.
		°F.
Orion	32	198 to 200
Camp	7	192
Minute Man	35	197
Little Giant	22	197
Sulphur Hills	25	195
Shore	17	194
Lake	25	195
Western	56	201½
Island	15	199
South	16	199
North	60	209
Yellow Crater	32	198
Total	356	.....

The following is a list of the geysers that are known to spout:

Geysers of the Shoshone Basin.

Name.	Interval.	Duration.	Max. height.	Remarks.
Union	About 5 days.	5 to 8 min. center cone; 10 to 13 min. north cone.	114 feet center cone; 59 feet north cone.	Has two or three periods, separated by three to eight hours.
Minute Man	35 sec. to 3 min.	2 to 30 sec	23 feet	There appears to be intervals of quiet longer than noted here.
Little Bulger	12 to 14 min	1 to 2 min	10 feet	
Little Giant	About 2 eruptions daily.	12 to 25 min	50 feet	
Small Geyser	.....	.....	20 feet	Time not taken.
Bead	1 min	2 min	5 feet	
Bronze	.....	.....	3 feet	Probably true eruption not seen.
Lion	30 min. to 1 hour.	2 min	10 feet	

BRONZE GEYSER SHOSHONE BASIN

CHAPTER XI.

HEART LAKE GEYSER BASIN.

The Heart Lake Basin includes a number of springs at the northeast base of the Red Mountains, on Witch Creek, a tributary of Heart Lake, and a small group near the Lake Shore.

History.—The earliest description of these springs that I can find is in Captain Barlow's report of the trip to the mountain named by him Mount Sheridan. In Lieutenant Doane's report,* Messrs. Washburn and Langford are said to have visited a group of springs near this neighborhood, but I cannot decide positively whether they were the hot springs at the head of Witch Creek or not. Lieutenant Doane says:

> Messrs. Washburn and Langford took a southerly direction [from Yellowstone Lake], toward the base of Yellow Mountain, for a distance of 11 miles. They saw from the divide the lake from which Snake River issues, also a small lake at an elevation of 800 feet above it. Beyond this divide they became entangled in an immense swampy, brimstone basin, miles in extent, abounding in sulphur springs, small geysers, and steam jets. The ground was covered with tufa, or calcareous (?) deposits in a thin scale, overlying hot, white mud. Mr. Langford's horse broke through several times, coming back plastered with the white substance and badly scalded. They were unable to penetrate to the lake on account of the instability of the footing.

The lake mentioned must have been one of three, viz, Heart Lake, Lewis's Lake, or Shoshone Lake, and of the three I think it must have been Heart Lake. If the white mud springs, near the head of Witch Creek, were encountered first, they might well deter the further progress of horsemen, as even on foot one is obliged to be extremely careful in his movements. All the known springs of Lewis's Lake and Shoshone Lake are on the western or southwestern sides of the lakes. It is possible that the springs encountered by Washburn and Langford were on some branch of Heart Lake other than Witch Creek. There is, however, no doubt that the Witch Creek Springs are the ones mentioned by Captain Barlow.† He says:

> The trail, after it was found, was not very plain, being so greatly scattered in some places that it was almost impossible to trace it. It led over a low divide, separating a small stream upon which we had camped, and which flows into the Yellowstone Lake, from the valley, descending towards the south, and whose waters flow into the Snake River. This valley eventually joins another coming in from the northwest, through which flows a warm creek supplied from a large group of springs along its borders. This stream is 20 feet across, 18 inches in depth, and empties into the small lake [Heart Lake] at the base of the high, snow-covered mountain [afterwards named Mount Sheridan] seen in the morning.

He also speaks of the springs near the lake, and on the next page (35) again speaks of the Witch Creek Springs, as follows:

> I followed the valley of the Warm Creek flowing into the lake near our camp. This stream has a rapid descent for 2 miles, and is fed by hundreds of hot and boiling springs of the same general character as those previously described. I saw some traces of sulphur, and also indications of geysers, though none were playing.

In 1872 Professor Bradley saw the springs while ascending Mount Sheridan, and mentions them thus:

> As we occasionally looked back we saw beneath us, on our left, the large cluster of hot springs which occupies the head of the valley of the longest tributary of Heart Lake, and, beyond, caught glimpses of Yellowstone Lake.

*Senate Ex. Doc., No. 51, 41st Congress, 3d session, p. 24.

†Captain Barlow's Report, pp. 33, 34, and 35. Senate Ex. Doc. No. 66, 42d Congress, 2d session.

In 1873 Professor Comstock visited the group which he describes under the head of "Thermal Springs at northeast base of Red Mountains, on source of Heart Lake."* He says:

> We passed a number of interesting springs along the banks of the stream, but the largest and most powerful members of the group were only seen at a distance. This collection has never been carefully examined, and it is probable that many new facts of value will yet be gathered here, if one may judge from the peculiarities of the two following bowls, which received some special attention.

He then described some springs which I have tried to identify. (See Witch Creek Springs farther on.) He also says:

> Many other bowls were observed than those described, some of which were of good size and quite clear, others turbid but not pasty, and a few veritable simmering solfataras, besides a large number which were only seen in the distance while climbing the peak which directly overlooks them.

We examined the springs of the Heart Lake Basin, in 1878, under disadvantages. We arrived at Heart Lake late on the evening of September 3 in a rain storm that continued for two days, so that our work was interrupted. We left early on the 7th, so that we had only one full working day in which the springs had to be mapped, described, and their temperatures taken. It was therefore impossible to make the map complete. The springs have not all been identified on the accompanying sketch map, as I was obliged to work independently of my colleague, Mr. Mushbach, but the principal springs are indicated. The Rustic Group had previously been mapped by Mr. Gannett, but a large group on one of the northern branches of Witch Creek was not visited, and does not appear on the map.

Geology.—The rocks of the Red Mountain Range and surrounding country are volcanic, being trachytic in their nature. Mr. Holmes's report will doubtless contain more specific information in regard to the rocks of the region.

In the valley of Witch Creek, near the lower end of the cañon, I observed a conglomerate or breccia composed of angular fragments of volcanic rocks. Near the head of the creek, clay banks give rise to numerous mud springs, although the general character of the springs is siliceous, derived from the underlying volcanic rocks through which the water first passes. Sulphur is abundant in these springs, and the sides of the gulches are stained by the oxidized iron of the deposits. Near one of the springs or pools of the Upper Group, on Witch Creek, some interesting specimens of hardened deposit were obtained, which were composed of layers of red and white deposit, which in place had the appearance of stratified rock. The Heart Lake Basin presents an interesting field for the chemical geologist, the deposits varying quite a good deal from those of the other basins of the Park in their physical features.

WITCH CREEK SPRINGS.

Witch Creek is the largest tributary of Heart Lake, and drains the nothern slopes of Red Mountain, which is the northern peak of the Red Mountain Range. It is a warm creek, deriving a large part of its water from the hot springs along its banks. It is about 4½ miles in length,

* Report upon the Reconnaissance of Northwestern Wyoming, &c. By Wm. A. Jones, p. 239.

DEPARTMENT OF THE INTERIOR,
U S Geological Survey of the Territories,
F V Hayden, U.S. Geologist in Charge.

SKETCH MAP

OF THE

HOT SPRINGS ON WITCH CREEK NEAR HEART LAKE, YELLOWSTONE NATIONAL PARK.

Plotted by

HENRY GANNETT, M.E.

From Notes and Sketches by

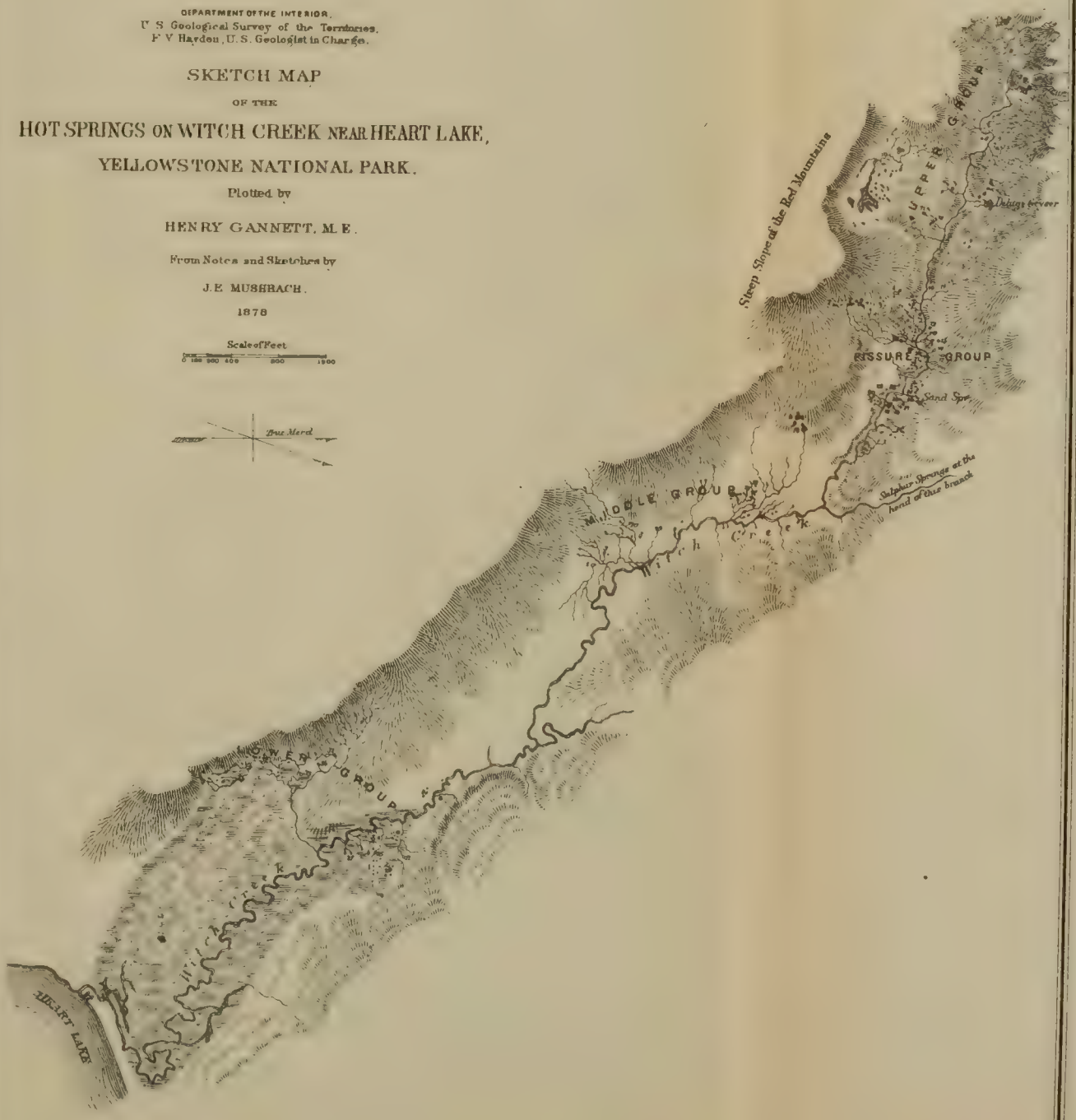
J.E. MUSHBACH.

1878

Scale of Feet

0 100 200 400 800 1600

True Merd



JULIUS BIEN & CO LITH

CRATER OF DELUGE GEYSER HEART LAKE BASIN.

and at the lower end flows with a most tortuous course through a marsh to the lake. The following temperatures were taken in the creek:

Location.	Temperature.	Time.	Temperature of air.
	°F.		°F.
Above the Upper Group	63	12.30 p. m.	57
Opposite springs 6 and 7 of Fissure Group	110	.....	.....
On branch from No. 18 of Fissure Group	129	.....	.....
Below junction of branch from No. 18, Fissure Group	109	.....	.....
Immediately below all springs of Fissure Group	120	.....	.....
Above the Middle Group	113	10 a. m.	53
Opposite the Lower Group	85	4 p. m.	63
Below the Lower Group	83	.....	.....
Mouth of the creek	78	.....	.....
Lake opposite creek	66	.....	59

At no point below the Upper Group did we find the water of the creek drinkable. For the purpose of description, I find it convenient to divide the springs on Witch Creek into four groups, viz, Upper Group, Fissure Group, Middle Group, and Lower Group, which will be described in the order here given.

UPPER GROUP.

This group of springs consists largely of mud holes, steam vents, and solfataras. The upper springs are between 300 and 400 feet above the level of the lake. The collection at Nos. 1 and 2 is made up largely of steam vents and mud holes. They extend up the slopes of the hills on both sides of the creek, which are brilliantly colored with reds, greens, yellows, and purple, on white grounds.

In No. 3 steam escapes at one end with a thumping noise. Below the hills in which Nos. 3 and 4 are situated, the creek enters a narrow cañon-like ravine, from which it flows with an abrupt turn to the left around a platform of geyserite on which the Spike Geyser (No. 5) is located. This geyser or spring will be best understood by a reference to the accompaning illustration (Plate XXXIX). The highest cone is about 2 feet and beautifully beaded, as are also all the smaller cones. This bead-like formation has a pearly luster. The water spurts constantly from small holes in the tops of the cones. Below the geyser, near the edge of the stream, is a white pool (*e*) from which a bridge of deposit extends over the creek. The outside of this white pool is brilliant in its coloring. Orange, lemon-yellow, and salmon colors are streaked on a milk-white ground in the utmost profusion, as though some painter had emptied pots of paint over the hard sediment from the springs. The table accompanying will give the temperatures observed. On the opposite side of the creek from the Spike Geyser is a ravine in a clay bank of brilliant greens and reds, in which numerous steam jets and mud springs exist. In the flat bordering the creek the ground is filled with simmering holes, and resembles some huge boiling vat.

Following down the creek we soon come to the Deluge Geyser (Plates XXXVII and XXXVIII), which is the handsomest basin in the group. It is situated at the base of a low hill, some feet above the level of the creek, and its overflow pours over a mound of deposit to reach the stream. It has an irregular-shaped basin, in which the water appears to have a deep bluish-gray tint. The border is handsomely ornamented with cushion-like masses of deposit, which are pink and yellow below and gray and white on top. Outside of the basin are pools of standing water, in which are delicate rose-colored, rosette-like masses. The

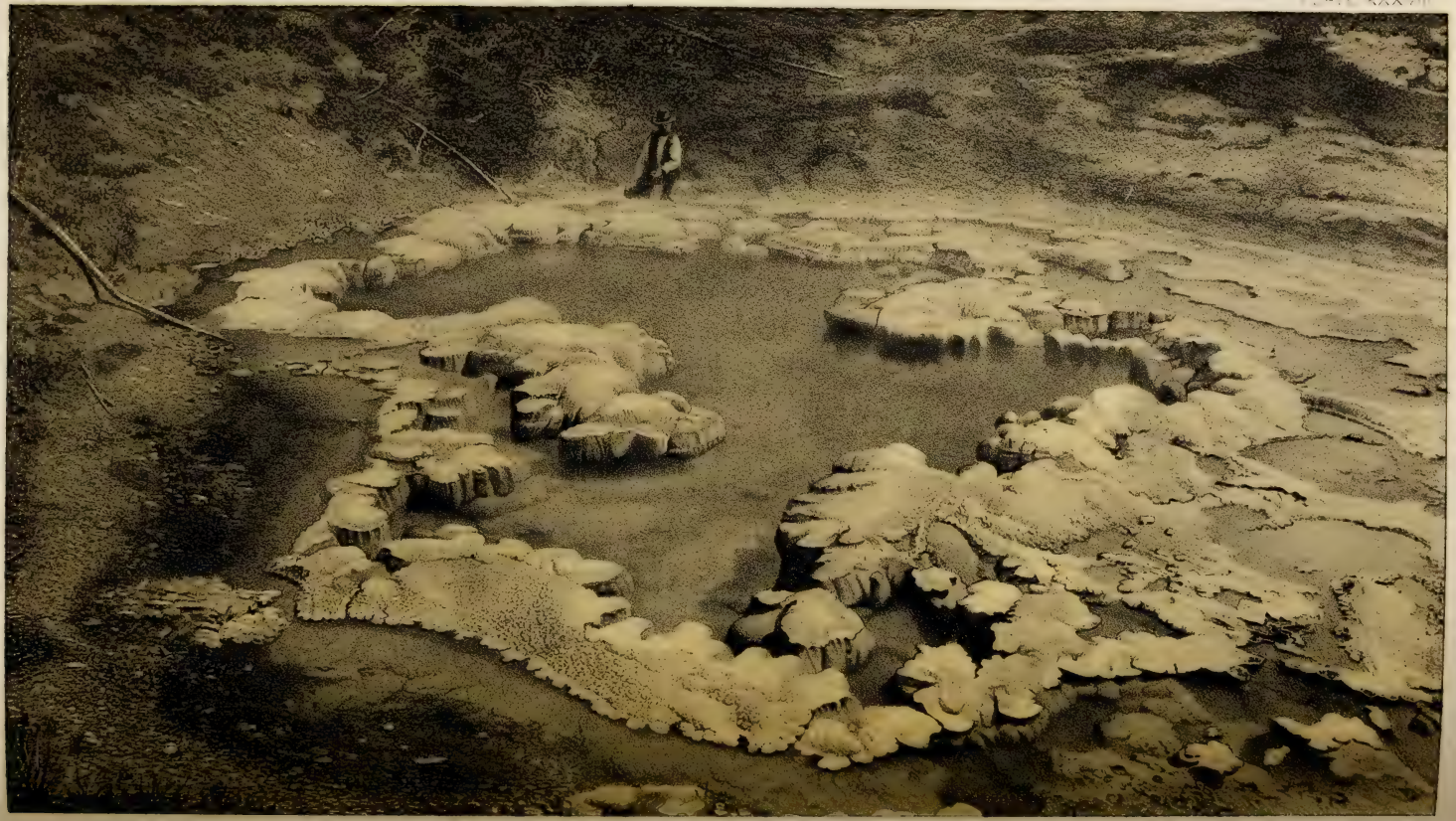
waterway leading from the geyser is lined with tints of salmon color and lemon-yellow. The water in this geyser rises and falls regularly, and after the basin is full bulges slightly. It has periods of geyseric action, which were not determined. It was seen in action by some of the party, and is said by them to have sent up a splashing mass of water to a height of 10 or 15 feet. Above the Deluge Geyser, on the same side of the creek, are a number of pools and springs. Among them a bright-red mud pool, in which the mud is very thin and actively boiling. On the oppssite side of the creek are several active springs, and back of them a group (No. 10) of large pools, mud springs, and turbid pools. Among them is a bulging spring with a white basin and bluish-tinted water.

Crossing the hill back of the Deluge Geyser and ascending the slope beyond to the head of a white gulch, we find a collection of steam holes and sizzling holes which mark the site of once very active springs. There are now several bubbling springs with wine-colored basins, in which the escaping water makes a sound like frying. Near it is a pool 8 feet long, with a temperature of 170° F., and opposite is a yellowish-lined pot 3 feet in diameter, with a dozen or more simmering spots with temperatures of 177° F. Above are holes with temperatures of 165° F., and below a clay mass full of simmering spots. These springs are about 500 feet above the level of the lake. Just below them is a large white flat, in which are about 24 mud cones from a foot to 2 feet in height, most of them white, some are tipped with red and yellow. Most of them are dry, others steam or spit out mud, and in the flat around them are steam vents and simmering holes.

The following table gives the springs of the group:

Table of the Upper Group—Witch Creek Springs.

Number and name.	Size, &c.	Temperatures.	Time of observation.	Remarks.
1 and 2				Mud pots and steam vents.
3	30 by 60 feet			Pool, light mud color, pinkish at edges.
4	75 by 100 feet			Light-greenish pool.
5. Spike Geyser	*a* is cone, 2 feet high; *b* is cone, above 1 foot high; *c* is 5 inches in height; *d* is about 6 inches high; all occupy space 3 feet diameter.	196	12 m.	Main geyser is a collection of spikes and cones; *e*, *f*, and *i* are holes on the same platform.
	f A collection of yellow-lined beaded sputterers.	*f* 197		
	e White pool	*e* 182		
	i Small hole near *f*	*i* 198		
6	*a* 5 feet diameter	*a* 162		Quiet bubbler in funnel-like basin across creek from No. 5.
	b 2 feet diameter	*b* 185		*b* is bulger.
	c 18 inches diameter	*c* 184		*c* has rising and falling of water.
7				Boiling spring in ravine opposite 5 and 6.
8. Deluge Geyser		180		Beautiful basin, with ornamented edge, and rosettes bordering outside.
9		170		Clear-water pools, with white basins and white scalloped borders; greenish-gray tinted water.
10				Collection of pools, mud springs, and one bulging spring. Some are clear, others milky or turbid.
11	2 pools, each 5 feet diameter			Opposite Deluge.
12		187		Clear white boiling spring.
13		*a* 165		These are at the head of White Gulch.
	b is 8 feet long	*b* 170		
	c is 3 feet diameter	*c* 177		
14				Mud cones below springs of No. 13.



CRATER OF DELUGE GEYSER, NEAR LAKE BASIN

FISSURE GROUP.

This group of springs (Plate XL) is located partly on a high, sloping mound and partly scattered along the sides of the creek which here descends rapidly in falls and cascades. Springs Nos. 1 to 5 are situated on a mound of hard deposit on the right bank. The first of these springs is shown in Plate XL *a*. The summit of this mound is about 40 feet above the level of the creek, opposite the junction of the small branch carrying the water from the springs on top of the mound. An accompanying plate presents a photographic view of this mound with its steaming springs, and shows spring No. 20 on the left in the foreground. The group extends to the point where the creek emerges from the gorge in the hills and enters the valley that reaches to the lake. The upper part of the group is about 200 feet above the lake level, and the lower springs are about 90 feet lower. It is probably in this group that the springs described by Professor Comstock* are located. I have tried to identify the springs and have concluded that his puffing spring is No. 20 of my catalogue. As to the sand spring, I am not so certain, although his description of the area in which it is situated corresponds to that around the group containing 23, 24, 25, &c. I had a similar experience to that which he relates,† as follows: Unsuspicious of the treacherous nature of the subsoil, of which no indications are visible, I incautiously sprang across the creek upon the flat, when I immediately sank nearly to the middle in a hot quagmire, from which it was difficult to extricate myself. The only result of this involuntary bath was a thorough soaking of apparel, including heavy undergarments, no mud adhering to the clothing. I came upon this area from the opposite side, and sank to my knees in the mire before I could get out of it. The turf appears to have merely covered a hot marshy area which collects the water from a number of the springs. I have given No. 23 the name Sand Spring, as its location appears to agree better with Professor Comstock's description than any of the others. He describes it as follows:

> The spring referred to lies at the upper end of the depression, which is here so narrowed that its walls almost inclose the spring on three sides. There are several centers of ebullition near the edges, the very hot water boiling up with force, greatly contaminated with white sand, with minute black grains interspersed.

My notes do not mention the fact of the sand boiling up with the water in No. 23, but as I was obliged to work here very hastily this may have been overlooked. I have, therefore, used Professor Comstock's name, especially as his is the first published description of any of the springs of the group. The Hissing Spring I was unable to locate. Professor Comstock describes it as follows:

> Just after reaching the basin in which these springs are located, a large spring, at some distance down the creek, suddenly ejected a dense mass of white vapor to a height of perhaps 25 feet, with a rushing noise which startled us all. This may have been a veritable geyser, but we were unable to detect any signs of a column of water from our point of view, below the Puffing Spring, 100 rods distant. The eruption lasted for about five minutes, ceasing rather gradually.

If I am right in locating the Puffing Spring at No. 20, and the Hissing Spring is a hundred rods below it, the latter must be one of the lower springs of the group. There is here one spring (No. 33) which is a constant boiler and spouter, which may have periods of steam spouting such as Professor Comstock describes.

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* Report of Reconnaissance of N. W. Wyoming, pp. 240, 241.
† Ibid, p. 240.

The following table contains nearly all the springs of the Fissure Group, with the temperatures that were taken:

Table of the Fissure Group, Witch Creek Springs.

Number.	Size and depth.	Temperatures.	Remarks.
		° F.	
1	Fissure 17 feet long by average width of 2 feet; *a b* is 2 feet long; *c d* is 3 feet long.	*b* 182 *c* 198 *d* 170	These are really on same fissure.
2	Fissure 23½ feet long; *a* is 3 feet wide, *b* is narrow crack, *c* is 18 inches wide by 12 feet long, *d* is 1 foot diameter.	*a* 170 *b* 160 *d* 174	*b* is a crack between *a* and *c*; outside are small holes.
3	Fissure 27 feet long; *b*, *c*, *e*, and *g* are on it; outside are *a*, *d*, *f*, *g*, *h*, and *i*.	*c* 185 *f* 180 *g* 180 *h* 187	*g* has strong flow of water; water from *h* sinks; *c*, *f*, and *i* are spouters.
4	21½ by 6½ to 13 feet. *a* is cone.	160 *a* 187 *b* 192	On the summit of the mound; *b* is bubbling hole.
5	Fissure 17 feet long. *c* is 3 by 4 feet	*a* 180 *b* 185 *c* 177	*a* boils out from under edge of geyserite; *b* is quiet white pool; *c* is connected with *b*. Above the end of fissure of 1, 2, and 3.
6	*a* is 2½ by 3 feet. *b* triangular, 18 inches on sides *c* small basin	*a* 175 *b* 178 *c* 155	*a* bulges from under deposit; *c* has a pinkish basin, with rim.
7		190	Yellow hole in the lower part of the mound near the river. It sputters and spurts.
8	*a* is 1 foot diameter *b* is 4 feet long *c* is irregular.	*a* 184 *b* 190 *c* 175	*a* is white bordered and near the river; *b* is a bulging spring; *c* has a horn-like mass at one end 2 to 3 feet high, evidently a crater broken down.
9	4 by 5 feet	185	Receives water from No. 4 and bulges at intervals.
10		170	These are in the gulch opposite 489. There are others in same gulch.
11		185	
12		190	
13		192	Salmon-colored; constant spouter, with basin just below; spouts to a foot or more.
14		165	Clear, pink-lined pool, probably connected with No. 15, which is just above.
15	Triangular sides are 6, 7, and 8 feet, respectively.	170	Broken-looking hole, without outlet; water is 3 feet from top.
16	3 by 3 feet	170	Bubbles slightly; below it is a hole in the grass.
17	13½ by 17½ feet	185–170	Blue, bulging spring, with yellow-beaded border; the water is violently agitated.
18	25 feet long	150	Pool with two greenish holes; receives water from the mound.
19	20 feet diameter	*a* 192 *b* 190 *c* 185	Constant bulger; water is thrown 2 or 3 feet in splashing masses; there are several bulging centers and pools on the outside.
20	Cone about 2 feet high	193 *a* 185	Spurts above the top of cone; it is evidently a geyser. *a* is on the mound near the river.
21		157	Quiet, pink, purplish-edged spring near the river, below No. 20.
22	Cone 6 inches high and throat 6 inches wide.	195	Geyser cone with quiet intervals; below it is a thumping hole, with pools; back of it are dead pools.
23	4 by 7 feet	170	Clear, gray basin.
24	2½ by 5 feet	175	Below No. 23 a clear spring.
25	Triangular, 3 feet on each side	187	Below No. 24 and near No. 26; it is a boiling spouter in constant action.
26	Basin 8 feet diameter; spring inside is 5 by 4 feet.	185	Yellow, spongy-looking crater at the foot of bluff near the creek; spouts and bulges 4 to 5 feet.
27	*a* 4½ feet by 18 inches *b* 1 foot by 6 inches	*a* 188 *b* 181	Both have clear water; *b* is constantly bubbling.
28	4 by 5 feet	138	
29		132	Green, turbid pool.
30	1 foot diameter	182	Back of 31 on same mound; it has a snow-white edge.
31	*a* 12 by 18 inches. *b* is 18 inches diameter.	*a* 174 *c* 175	*a* and *b* are together about 5 feet from creek; *c* is at the edge; there are other holes on the mound; *b* is a quiet spring.
32	2 feet diameter	190	On the edge of creek.
33	6 by 7 feet	185	Bulger constantly agitated, throwing water 2 feet at intervals of a few seconds.
34	14 by 17½ feet	130	Large, green pool.

GEYSER CONE, HEART LAKE BASIN

DESCRIPTION.

The springs from which the group takes its name are situated in a fissure on top of the mound on the right bank of the creek opposite the falls and cascades. The upper portion of this fissure is well shown in Plate XL*a*. It is situated at the base of the hill, and below it the deposit has a steep slope to a ravine which contains several large springs. It is over this slope that the overflow from the fissure passes. The fissure as exposed on the surface is about 300 feet in length, with numerous holes and springs, of which the principal ones are given in the table under Nos. 1, 2, and 3. Steam escapes constantly from the fissure, as shown in the plate already referred to. The springs of No. 5 are doubtless on the line of the same fissure, which is probably continuous beneath the hard crust. This would give it a length of over 600 feet. Springs Nos. 4, 6, 7, 8, and 9 are also on the same mound, as shown by the map.

No. 4 is a very handsome spring basin on the summit of the mound, and has a white basin with a yellowish edge. This is flat-bottomed, with a deeper, long, irregular basin in the center. There are also a number of extinct springs scattered over the mound.

The gulch in which Nos. 10 and 11 are located has also a number of springs located in the bed of the stream. They are all unimportant. Following down the creek from these, on the left bank, we come to the collection comprised under Nos. 12–17. Of these, No. 13 is the most interesting. It is shown in the illustration, being marked by the first steam column on the right side of the stream, as seen in looking at the picture. It is situated at the base of a rock, and has a basin bordered with salmon-color, pink, and greenish-yellow spongiform masses of deposit. This rises 2 feet above the spring at the back. Whenever seen the spring was in violent action, spouting to the height of a foot or two. Close to it is a small quiet spring.

No. 17 is a very handsome spring, with a yellow-beaded border, in which the water has an indigo-blue tint. It is some distance above the creek level and back from its edge. Back of the spring are numerous red and green tinted steam vents. The water in No. 17 has a temperature of 185° to 190°, according to the point where it is taken, and is constantly and violently agitated.

Opposite No. 17 is the subgroup, of which No. 20 (Puffing Spring (?)) is the center. It is on a mound on the right bank of the creek, above which it rises about 20 feet. This mound is composed of hard rocky deposit, and has on its summit a cone 2 feet high of gray-beaded silica. In the top of this is a yellow, triangular orifice, measuring 2 feet on the sides. In this the water has a temperature of 193° F. It spurts irregularly above the top of the cone, and, judging from the appearance of the deposit surrounding it, must have periods of geyseric action. There are several small openings in the mound outside of the cone, one of which, near the river, has a temperature of 185° F.

Professor Comstock has the following description of the Puffing Spring:

> The first to be described is situated on a kind of platform upon the right bank of the stream below the main fall, but near the side of a rambling cascade. The orifice is not large and the vapor, which is constantly emitted, issues from the solid rock in a manner closely resembling the puffing effusions at the Steamboat Spring [on Yellowstone Lake]. The expanded chamber, which probably exists at no great distance beneath, is not visible from the surface. The resonance of the escaping vapor is increased, with the production of a slight echoing sound, by the wall of the gorge, which partially incloses the spot somewhat after the manner of an amphitheater. The result is a noise not unlike that of a hydraulic ram in action.

In many points this answers the description of spring No. 20. The latter is on a platform of deposit on the right bank of the creek, which is here broken into cascades, as is seen in Plate XL. It is also below the main fall in the creek.

The only other mound or platform likely to be the one Professor Comstock mentions is the one with the fissure. My only hesitation arises from the fact that I am unable to locate his camp, as his description would seem to indicate the presence of falls of considerable extent. He says:

> Our little party was camped in a sheltered spot near the brink of a high fall on one of these creeks at the northern end of the range, several hundred feet above the lake, which was not in sight from that point.

His camp was surrounded with springs, and the only creek at the north end of the range with springs is the Witch Creek. The Fissure Group, also, as I have already said, is about 200 feet above the level of the lake, and it is here that the only falls in its course are located. These reasons, I think, are sufficient to identify the locality as the same one.

On the left bank of the creek below the springs enumerated in the table there are a number of springs as shown on the map, and on the creek joining Witch Creek, below the group, there is a large collection of springs, which was not visited owing to our limited stay at Heart Lake and the prevalence of bad weather.

MIDDLE GROUP.

In the map of this group the numbers of only a few of the springs are given. Being obliged to work independently of the topographer the numbers were not placed on the sketches in the field until after the springs were left, and then only those were numbered which were positively identified. The group is located almost entirely on the right side of the creek. A great many of the springs are on marshy ground, and to avoid this the trail to the lake has to keep back of the springs near the foot of the hills. Below No. 1 the water stands on the surface, spreading out on a flat which extends into the timber. None of the springs in this group deserve special mention, and the reader is referred to the table which follows for descriptions of the individual springs. None of the temperatures are high, most of the springs being turbid or mud-holes hid in the grass.

Table of the Middle Group, Witch Creek Springs.

Number.	Size and depth.	Temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.			
1	*a* is 3 feet long *b* is 2 feet long *c* is 4 by 4 feet	*a*130 *b*159 *c*150			*a* and *b* are fissure-like springs, which have a white-bordered outlet from which water spreads out on a large, red, flat place; *c* is a small, square pool.
2					Dead pool back of No. 1.
3	9½ by 2 feet	140			Large green pool. In the grass back of this are a number of pools.
4	3 by 7 feet	165	10 a. m.	53	Yellow-white basin, with green edge and green outlet.
5	*a* 3 by 6 feet *b* 2 feet diameter	*a*150 *b*130			*a* is white basin, green at lower end; *b* is green-lined, on water-way just below *a*.

PLATTE SPRINGS, HEART LAKE BASIN

Table of the Middle Group, Witch Creek Springs—Continued.

Number.	Size and depth.	Temperatures.	Time of observation.	Temperature of air.	Remarks.
		° F.			
6	*a* 15 by 17½ feet	*a*150			*a* is the principal spring, a white-lined basin with red and yellow edges; *b* is a red-lined pool back of *a*, and connected with it; *c* is back of *b*, and disconnected; *d* is a fissure, with several holes below *a*.
	b is 3 by 6 feet	*c*140			
	c is 2 by 3 feet				
	d is a fissure				
7	3 by 3 feet	155			Brown-edged, yellow-gray basin.
8					Red basin above No. 7; more in gully above.
9	2 by 3 feet	175			Brown-lined basin; back of it is an old geyser tube, now dead.
10	2 by 3 feet	145			Green-lined pool in gully.
11	Fissure-like, 18 inches wide	155			
12	3 feet diameter	160			Gray-white basin.
13	2 feet by 18 inches	138			Back of 11 and 12, near the trail.
14	20 by 30 feet	115			Back from creek, near trail.

LOWER GROUP.

The Lower Group is near the upper margin of the swampy valley and consists of two subgroups. The first includes springs Nos. 1 to 30, and is on the left bank of creek on a wide flat which rises gently as the creek is left. The springs of this subgroup are partly on hard deposit and partly on marshy ground. Only a few of the springs on the map are numbered, for the same reason that prevented the numbering of the springs in the Middle Group. The second subgroup contains a large number of springs on a small branch which joins the creek from the south or right side. The springs extend back as far as the base of the hills. Only a few were visited, as the numbering on the map indicates. The surface about most of them is marshy, and a number are merely oozing holes in the marsh. No. 23 is the handsomest spring in the collection. It is a transparent, blue pool, with an ornamental raised rim and two outlets. It is an intermittent spring.

The springs of the Lower Group do not deserve any extended description, and the accompanying table will present all the facts that are of interest in connection with the springs.

Table of the Lower Group, Witch Creek Springs.

Number.	Size and depth.	Temperatures.	Remarks.
		° F.	
1	8 by 10 feet, 20 feet deep	180	White basin, with snowy border and blue-tinted water.
2	2 by 3 feet	180	Small, black bulger.
3	1 foot diameter	170	Considerable overflow.
4	7½ by 11 feet	150	Green-lined basin; outlet joins that of No. 5.
5	Spring and pool	*153	The pool receives water from the springs above.
6	1 foot diameter	190	Near No. 7.
7	5 feet long	190	Two bulgers in mound, of pearly deposit.
8		176	White mound, with two basins, one having a boiling center; green outlet.
9	*a* 2 feet by 18 inches	*a*143	No outlet to *a*; *b* has outlet.
	b 2 feet by 18 inches	*b*158	
10			Dead steam hole.
11	4 by 4 feet	165	Gray basin.

Table of the Lower Group, Witch Creek Springs—Continued.

Number.	Size and depth.	Temperatures.	Remarks.
		° F.	
12	}	------	Dead springs.
13	}		
14	1 foot diameter	185	Spouters.
15	4½ by 5 feet	195	
16	3 by 6 feet	160	White basin, which receives overflow from No. 15.
17	2 by 4 feet	145	Red-bordered, green basin below No. 16; receives water from Nos. 15 and 16.
18	8 inches diameter	180	Small, white spouter, with green border.
19	3 by 5 feet	174	White-bordered.
20	3 feet long	164	White basin.
21	3 by 7 feet	160	Three openings in the irregular basin.
22	2 by 4 feet	175	White basin.
23	18 inches by 3 feet	194	Beaded border in geyserite.
24	6 inches by 1 foot	194	Pearly-beaded spouter.
25	*a* 6½ by 7 or 5 feet	*a*180	*a* boils and spouts a foot or more; *b* is a white basin; *c* is a small hole. Besides these there are other spouters on the same platform.
		*b*175	
		*c*198	
26	*a* 4 by 4½ feet	*a*150	Two yellowish, white-lined basins; quiet; a small bubbler is near *a*.
	b 3 feet diameter	*b*125	
27	*a* 3 feet diameter	*a*150	These springs are in the grass, and have quiet, almost dead, springs near them.
	b 4 feet long	*b*128	
	c 4 feet diameter	*c*125	
28	5 feet long	115	Green-lined basin in a mound near the creek.
29	6 by 10 feet	125	Green-lined pool.
30		189	Old geyser cone, in which the water is 3 or 4 feet below from the top.
31	12 feet diameter	177	
32	27 by 39½ feet	150	Large, brown-lined pool.
33	11 by 19½ feet, 15 feet deep	160	Beautiful blue spring.
34	16½ by 8½ and 9 feet	155	Heart-shaped spring.

* Spring.

RUSTIC GROUP.

For the notes on this group I am indebted to Mr. Gannett, who made the accompanying map of the group. No temperatures were taken, and during my visit the limited time at our disposal prevented any more notes being added to those of Mr. Gannett. This group is at the base of the mountains, about an eighth of a mile back from the lake and about the same distance below the mouth of Witch Creek, and occupies an area of about 4,000 square yards. Plate XL*b* gives a distant view of the group, with Mount Sheridan rising above it enveloped in clouds. Captain Barlow refers to the group on page 34 of his report* as follows:

> Just at the foot of this mountain, near the lake shore, are four or five boiling springs, one of which is a geyser of considerable importance, throwing jets of water, at frequent intervals, to the height of 15 feet.

In Comstock's description of his trip to the Heart Lake Basin† I find no reference to this group. The principal spring or geyser in the group is the Rustic Geyser (Plates XLI and XLII). This has a basin 8 by 9 feet, bordered by logs, which are coated with a crystalline, semi-translucent deposit of geyserite. These logs were evidently placed around the geyser by either Indians or white men a number of years ago, as the coating is thick and the logs firmly attached to the surrounding deposit, which occupies an area of about 31 feet diameter.

* Ex. Doc. No. 66, Senate, Forty-second Congress, second session, p. 34.
† Report on Reconnaissance of N. W. Wyoming, by Captain Jones, p. 239.

HEART LAKE AND MOUNT SHERIDAN RUSTIC GROUP IN DISTANCE

RUSTIC GEYSER, HEART LAKE BASIN

The following observations on the eruptions are copied from Mr. Gannett's notes.

Boiling.	Emptied.	Stopped.	Height.	Pulsations.
h. m. s.	*h. m. s.*	*h. m. s.*	*Feet.*	
10 46 00 a. m.	10 50 00 a. m.	10 51 00 a. m.	45	.....
11 02 00 a. m.	11 05 30 a. m.	11 06 36 a. m.	35	47
11 18 30 a. m.	11 21 00 a. m.	11 22 00 a. m.	40	45

The eruption, therefore, begins with a preliminary agitation, lasting from $2\frac{1}{2}$ minutes to 4 minutes, and the duration of each eruption noted was 1 minute, and the interval between the beginnings of eruption was just 15 minutes in each case; so, judging from the few notes presented, this geyser is very regular in its periods of action.

Columbia Spring (Plate XLI *a*).—This is a very handsome, large basin, measuring 48 by 53 feet. It has a broad, white border, which projects in plate-like masses over the water of the spring. There are two large outlets bordered by the same character of deposit, and in the channels are rosette-like pieces resting on slender, stem-like pedestals.

Prometheus Spring is 6 by 8 inches, but is an active, boiling hole on the side of the hill. There are several small, boiling holes back of the Rustic. The following are the sizes of some of the springs: No. 4 is a pool; No. 1, 20 by 20 inches; No. 2, 4 by 6 feet; No. 3, 7 by 14 feet; No. 5, 5 by 6 feet; No. 6, 3 by 6 feet; No. 7, 1 by 5 feet; No. 8, 7 by 8 feet.

RECAPITULATION.

The following is a recapitulation of the springs of the Heart Lake Basin:

Group.	Number of springs.	Highest surface temperature.
		° F.
Upper Group, Witch Creek Springs	25	198
Fissure Group, Witch Creek Springs	53	198
Middle Group, Witch Creek Springs	20	175
Lower Group, Witch Creek Springs	40	198
Rustic Group	11	.....
Total number of springs noted	149	

The following is the list of known geysers. The details in regard to them are meager:

Name.	Interval.	Maximum height.
Spike Geyser	Not known	Not known.
Deluge Geyser	Not known	15 feet.
Puffing Spring or Geyser (?)	Not known	Not known.
Rustic Geyser	15 minutes	45 feet.

CHAPTER XII.

HOT SPRINGS OF LEWIS LAKE AND SNAKE RIVER.

In this chapter I will refer briefly to several comparatively unimportant spring areas which were not examined in detail by us in 1878, but ought to be described here for the sake of completeness. If the southern boundary of the Park should be changed to a line farther north, as has been proposed,* the springs on Snake River which are described in this chapter would be outside the limits of the Park.

The Snake River Springs were passed in 1863 by the prospecting party with which Captain De Lacy was connected, and they are mentioned by him on page 128 of the Contributions to the Historical Society of Montana, Vol. I. In 1872 the Snake River Division of the United States Geological Survey visited them, and the descriptions given in this chapter are from the descriptions of members of that party.

The geology of the localities in which the springs here described are situated does not differ from that of the Heart Lake and Shoshone Basins.

HOT SPRINGS OF LEWIS LAKE.

The springs on Lake Lewis were not visited by us, and the following account of them is taken from Professor Bradley's report (Rept. U. S. Geol. Surv. of Terr., for 1882, 1873, p. 250):

On the west end of the lake, near its northern end, numerous hot springs occur over a considerable area, a few being seen far up on the western ridge. Those near the lake were examined by Mr. [W. R.] Taggart, who reports as follows:

The hot springs found on the west bank of Lewis Lake occur mostly in two groups, separated by a low ridge. In the first group ezamined, all the springs issued from the sides of a marsh, and were mostly covered either with masses of leafy vegetation or with the soft, thick, pulpy masses of fungoid growth so common about the hot springs of the Fire Hole Basins. Some of the springs were constantly bubbling with an escaping gas, whose character was not ascertained. The temperatures of all the springs are low. A few of them are as follows: 112°, 122°, 124°, 126°, 128°, 130°, 138°, 140°, 148°. As an interesting fact, I noted that all the springs whose temperatures reached or exceeded 120° had the growth of fungoid pulp or a deposit of gray geyserite, while those cooler than 120° were covered with leafy vegetation. This cluster of springs is evidently the last remnant of a much more active group, since all along the shore of the lake at this point there are large deposits of old geyserite. At some points this extends far out into the lake.

The second group of springs differs from the one just described, in that its vents are larger and the water hotter. The springs are surrounded by solid ground, and in their general features resemble the hot springs of the Fire Hole Basins, so that they need no general description. The following are the temperatures and sizes of a few of the principal ones: 1, 152°, 2 feet in diameter; 2, 156°, 10 by 6 feet; 3, 176, elliptical about 40 by 20 feet.

SPRINGS ON SNAKE RIVER.

Under this head I will include the springs on Snake River and its tributaries, not already given in the basins located on drainage of the Snake.

Springs at junction of Snake and Lewis or Lake Fork.—On the east side of Snake River opposite the mouth of Lake Fork is a small group of unimportant springs, in which Mr. Mushback took the following tem-

* Annual Report of the Superintendent of the Yellowstone National Park, 1880, page 25.

MAP

ON THE

RUSTIC GEYSER GROUP

NEAR

HEART LAKE

Scale of Feet:

0 25 50 75 100

JULIUS BIEN & CO LITH

COLUMBIA SPRING RUSTIC GROUP HEART LAKE BASIN

GEYSER BASIN, UPPER GEYSER BASIN.

peratures on August 9, the temperature of the air being 80° F. Near the river, beginning at the north end, the following were the temperatures: 173° F., 180°F., 167° F., 135° F., 150° F., 156° F., 166° F., 172° F., 174° F., 165° F. Some of these are sputtering springs and have cones. Back of the river on a small ridge the following were taken, viz, 160° F., 160° F.

In Small Creek bottom, farther east, the following: 155° F., 155° F., 155° F., 163° F., 110° F. Most of these springs have clear water and are boiling and sputtering constantly. The group, as the map shows, is near the south line of the Park. About 12 miles up the Snake is a group described by Professor Bradley in the report for 1872. These springs are located near the remarkable bend in the river, which is shown on the map, and they fall, therefore, within the limits of the Park. They might be known as Snake Cañon Group, which is the name I will use here to designate them.

Snake Cañon Group.—Professor Bradley* describes this group as follows:

> Just at the mouth of the narrow cañon the river bends sharply to the right and then to the left, so that the form of the slopes gives the descending traveler reason to expect here a large affluent; but none exists. About a mile lower we came suddenly upon a small basin of hot springs, most of which are now nearly extinct, though some large mounds on the river bank give evidence of great activity in former times. The active vents seen were all in the bed or on the bottoms of the river, so that their flow was more or less mingled with river water, and no temperatures were taken. The deposits are siliceous. Mr. Taggart found near here, at the foot of the second terrace, several conical depressions from 30 to 40 feet deep and from 75 to 100 feet in diameter, which *might* have been old spring basins, though their origin is by no means certain. At the bottom of one of these lay two dead rabbits upon which there were no signs of violence. No other signs of escaping gas were noticed.

Farther west, above the mouth of Lake Fork, Professor Bradley describes† some springs which are just inside of the limits of the Park. They were not seen by us, and I therefore give his description:

> The high ridges which form the slopes about Lake Lewis bear back from the river and form no part of its lofty cañon-walls. Between the river and this upper slope, on the west side, a large stream gathers its waters from the abundant springs of the mountains, and occupies a broad, flat valley on the lower level, filled with beaver-dams, whence it rushes through a narrow-winding cañon and over a 30-foot fall to meet the river about a mile above its junction with the Snake. On the foot-slopes of the mountain, along the west side of the beaver-dam flat, there are considerable numbers of warm springs oozing out, and considerable accumulations of siliceous deposits are indicated by the soil. A small run formed from a number of these springs gave a temperature of 101°. It is possible that active springs of some size exist in this neighborhood, but the contrary is indicated by the extensive bodies of dense timber, which also hinder exploration.

Professor Bradley also refers to the springs at the mouth of Lake Fork as follows:‡

> Immediately opposite the camp at the mouth of Lake Fork there is a considerable cluster of dead and dying hot springs. Several mounds indicate the former positions of geysers of considerable size. The temperatures of ten springs were taken by Mr. Taggart, varying from 102° to 158°. Three were above 150°. The deposits are now rapidly disintegrating. Upon one large conical mound this process had developed a columnar or fibrous condition of the geyserite. Similar spring deposits also occur on the west side of the river from one to four miles below this camp, and some of the mire-holes so common in the Fire Hole Basins were also encountered. Upon looking back from below, two large columns of steam were seen about a mile up the Beaver-Dam Creek, which seemed to indicate the possibility of geysers still existing there.

Springs on Thirsty Fork of Henry's Fork of Snake River.—In 1872, Mr. Bechler, topographer of the Snake River Division of the Survey, spent

* Report U. S. Geol. Survey for 1872, 1873, p. 256.
† Report U. S. Geol. Survey for 1872, 1873, p. 257.
‡ Report U. S. Geol. Survey for 1872, 1873, p. 259.

several days on a trip of examination of the divide west of the Fire Hole River. Professor Bradley, speaking of this trip, says:

> At two points the party found small clusters of hot springs, some of which spouted a little, but no considerable geysers.*

One of these localities is indicated on the "Map of the sources of Snake River" as Mud and Sulphur Springs at the head of Thirsty Fork.

Grand recapitulation of springs and geysers of Yellowstone National Park.

TABLE OF SPRINGS.

Locality.	Number of springs.
Mammoth or White Mountain Hot Springs of Gardiner's River	78
Springs of Yellowstone River below the Grand Cañon and on East Fork	47
Hayden's Valley Springs	128
Springs of Yellowstone Lake	112
Pelican Creek Springs	11
Gibbon River Springs	121
Lower Geyser Basin of Fire Hole River	693
Upper Geyser Basin of Fire Hole River	440
Third Geyser Basin of Fire Hole River	20
Shoshone Geyser Basin	356
Heart Lake Geyser Basin	149
Hot Springs of Lewis Lake and Snake River	40
Total number of springs	2,195

The table just given, of course, does not include all of the springs of the Park, but all that are mentioned in the foregoing chapters. It is defective, more or less, in all the localities except the Mammoth Hot Springs, the Gibbon Geyser Basin, the two Fire Hole Basins, and the Shoshone Basin. The total number of springs known within the limits of the Park is probably about 3,000.

TABLE OF GEYSERS.

Name.	Locality.	Maximum height of column of water.
		Feet.
Muddy Geyser	Hayden's Valley	40
Mud Volcano	do	
Pseudo Geyser at Boiling Springs	do	8
West Pelican Geyser	Pelican Creek	15
Pelican Creek Mud Volcano	do	75
Black Geyser?	Gibbon Geyser Basin	10
No. 15 Geyser	do	20
Mound Geyser?	do	
Steamboat Vent	do	100
Echinus Geyser	do	20
Pebble Geyser	do	50
Pearl Geyser	do	
New Geyser?	do	
Minute Geyser	do	40
Monument Geyser	Monument Geyser Basin	
Oblique Geyser	do	75
Fountain Geyser	Lower Geyser Basin of Fire Hole River	50
Jet Geyser	do	15
Spasm Geyser	do	
Clepsydra Geyser	do	30
Fitful Geyser	do	3
Bead Geyser	do	
Pink Cone Geyser?	do	

* Report U. S. Geol. Survey of the Terr. for 1872, 1873, p. 234.

TABLE OF GEYSERS—Continued.

Name.	Locality.	Maximum height of column of water.
		Feet.
Steady Geyser	Lower Geyser Basin of Fire Hole River	30
Young Hopeful Geyser	do	15
Great Fountain Geyser	do	100
White Dome Geyser	do	.....
Fortress Geyser?	do	.....
Mound Geyser?	do	.....
Rosette Geyser	do	30
Catfish Geyser?	do	.....
No. 38 Geyser	do	20
Soda Geyser	Upper Geyser Basin of Fire Hole River	.....
Restless Geyser	do	.....
Sentinel Geyser	do	20
Grotto Geyser	do	60
Fan Geyser	do	60
Riverside Geyser	do	80
Giant Geyser	do	200
Young Faithful Geyser	do	30
Oblong Geyser	do	.....
Spray Geyser	do	.....
Comet Geyser	do	30
Punch Bowl Geyser	do	.....
Castle Geyser	do	200
Castle Geyser, jr.?	do	.....
Grand Geyser	do	200
Saw Mill Geyser	do	20
Tardy Geyser	do	.....
Bulger Geyser	do	5
Turban Geyser	do	25
Spasmodic Geyser	do	5
Old Faithful Geyser	do	150
Giantess Geyser	do	250
Bee Hive Geyser	do	219
Trinity Geyser	do	60
Niobe Geyser	do	75
Three Crater Geyser	do	20
Solitary Geyser	Third Geyser Basin of Fire Hole River	70
Union Geyser	Shoshone Geyser Basin	114
Minute Man Geyser	do	23
Little Bulger Geyser	do	10
Little Giant Geyser	do	50
Small Geyser	do	20
Bead Geyser	do	5
Bronz Geyser?	do	3
Lion Geyser	do	10
Spike Geyser	Heart Lake Geyser Basin	.....
Deluge Geyser	do	15
Puffing Spring or Geyser	do	.....
Rustic Geyser	do	45
Total number of geysers enumerated		71

This table of the geysers is as complete as can be made with the data at command. A few not known *positively* to be geysers have been included, but are marked with a query. In the case of others that are included no heights are given, because they have never been measured nor estimated. Some of them have not been seen in action but are placed in the list because the forms of their basins or bowls and the character of the surrounding deposits indicate them to be geysers.

PART II.

THERMAL SPRINGS AND GEYSERS.

CONTENTS.

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INTRODUCTION.

In this portion of the report I propose to give briefly a description of the geyser areas of Iceland and New Zealand, for the sake of comparison with our Yellowstone National Park, and to make clearer some of the facts detailed in Part III. I have also added short chapters on the thermal springs of other portions of the world.

In going over the literature of thermal springs, I found that there was no one place in which I could find the subject of their distribution thoroughly treated of, and I concluded to bring together in this place the result of my search, which, although not so complete as could possibly be made with more time, will give a good idea of the wide distribution of hot springs and geysers, and their connection with volcanic action either recent or extinct. In the catalogues appended to the different chapters, there may be some duplication of localities, but I have tried to avoid it as much as possible. The different spellings of various places by different authors, and the changes in geographical boundaries, have rendered it probable that there may be some duplication, but I feel assured that if so it is very slight.

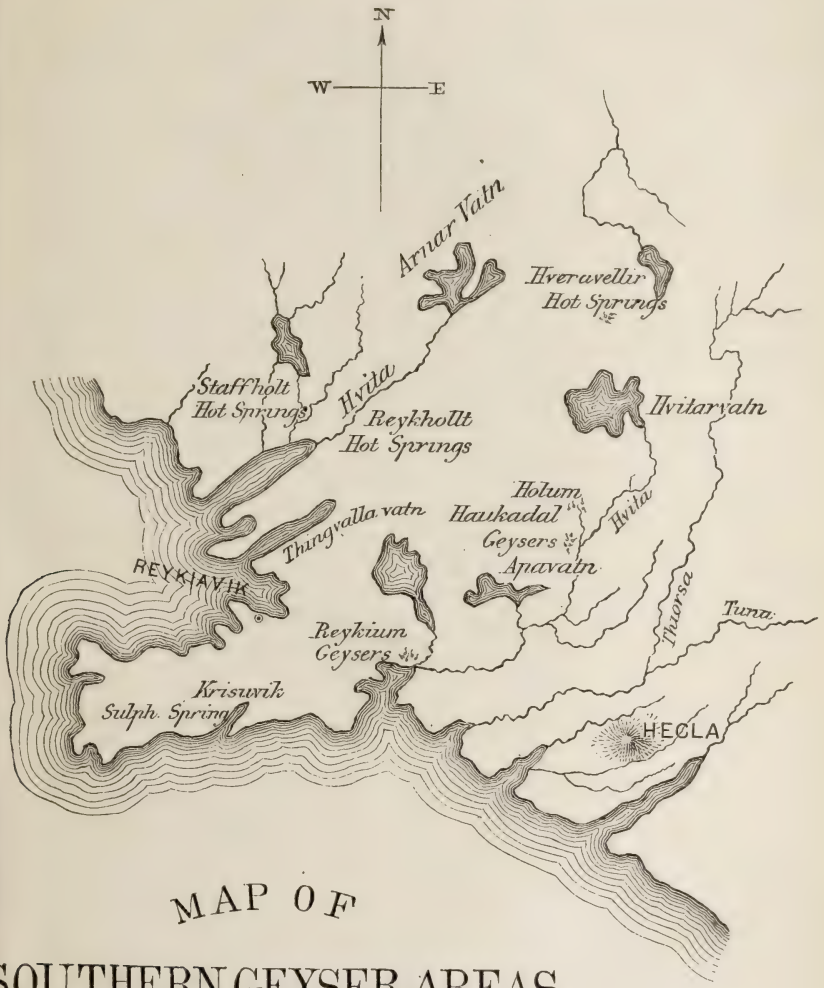
CHAPTER I.

THERMAL SPRINGS AND GEYSERS OF ICELAND.

Iceland has always been noted for its hot springs, and was for a long time the only remarkable geyser locality known. The very name *geyser* testifies to Iceland's historical precedence as the land of geysers. At present, however, it is rivaled if not excelled by the New Zealand and Yellowstone localities.

The hot springs of Iceland may be conveniently divided into three areas, viz:

1st, that in the north or northeastern portion of the island, about



MAP OF

SOUTHERN GEYSER AREAS

(MAIN AREAS.)

OF ICELAND,

Scale of Miles

10 20 50

Krabla and the Lake Myvatn, including also an area about the volcano Askja in the eastern part of the island.

2d, the western area, including several localities near Breidafiord.

3d, and most important, the southern or southwestern area, in which are located the Haukadal geysers, which are world-renowned. This area is about 100 miles long by 50 miles wide if we consider Hveravellir the most northern locality, and Krisivuk the most southern, and the geysers of Haukadal the eastern, and the springs Reykiadal, near Reykhollt, the western limit. Within these boundaries there are about eight or nine different spring localities.

This third area is in the southwestern part of the island, and contains three or four large lakes and several large rivers. The three principal of its eight localities are Hveravellir, Reikum, or Reykium, and Haukadal.

HVERAVELLIR.

Hveravellir, or "plains of the hot springs," is about 50 miles north of the Haukadal geysers. There are about a dozen principal springs and geysers, some of which spout to a height of 18 or 20 feet. One cone, 4 feet high, is called "Auschrolinn," or the "Roaring Mount," from which a great volume of steam escapes with great violence and a tremendous noise. One geyser, called the "Grand Jetter," has an eruption of steam that lasts more than three hours, after which it fills with water and has regular water eruptions. There are large surfaces covered with the remains of ancient springs, one mound of an extinct geyser being twice the size of the Great Geyser at Haukadal.

Olafsen and Povelsen, in 1772, and Henderson, in 1815, described these springs as being most wonderful and of great activity, but Baring-Gould, in 1863, speaks of them as having greatly diminished both in numbers and activity.

REIKUM OR REYKIUM.

The springs at Reikum, sometimes called the "Little Geysers," are next in importance to those of Haukadal, from which they are distant about 50 miles in a southwesterly direction. There are about one hundred springs in all, scattered over an area of about 50 acres. The following are the principal geysers:

Geyser.—This namesake of the great fountain at Haukadal has two apertures, the southern one of which is a constant spouter throwing the water from three to twelve feet. The second aperture is about 10 feet from the first and has eruptions about fifteen times in the twenty-four hours. Vast clouds of steam escape with the water, which reaches a height of 30 to 40 feet, the action lasting three or four minutes and sometimes nearly fifteen minutes.

Badstofer.—This fountain is near the river and has an irregular aperture. The eruptions take place about every five minutes, and begin with a concussion, after which the water is ejected, some of the jets being perpendicular, reaching a height of 12 feet, and others oblique, attaining a height of 20 feet. The action lasts about ten minutes, when the water sinks and alternately rises and falls until the next eruption takes place.

Besides these geysers there are numerous boiling springs, steam vents, and mud springs.

HAUKADAL.

The Haukadal geysers and springs are about midway between Hveravellir and Reykium, about 50 miles northwest of Mount Hecla, at the

foot of a range of hills of 300 to 400 feet in height, which rise from the northern edge of a plateau of volcanic rocks. This plateau is crossed by the Hvita, one of the largest rivers of Iceland, and is about 360 feet above sea level at Haukadal. Within a circuit of two miles a hundred or more hot springs may be counted, although the principal geysers and springs are within an area of a quarter of a mile by 300 feet.*

The earliest writings in relation to Iceland are silent in regard to the geysers. Are Frode, A. D. 1075, in the Icelandic annals, makes no mention of them, although he lived near their present locality. On the other hand, as Henderson says, "it is equally surprising that not the least notice should be taken of their appearance, allowing them to have broken forth subsequent to that period." It must be remembered, however, that in all but highly-civilized nations physical events that do not have an immediate effect on their worldly interests are viewed with indifference or apathy. Pliny gives a circumstantial account of the eruption of Vesuvius in A. D. 79, but does not mention the destruction of of Herculaneum and Pompeii. Forbes,† from a calculation based on the rate of deposition, gives a probable age of 1,036 years for the age of the Great Geyser. This, however, as I shall endeavor to show in another place (see Part III), is based on an error.

The earliest mention of the geysers is by Saxo Grammaticus, who wrote in the twelfth century and referred to the Geyser in his preface to the History of Denmark. In the middle of the seventeenth century Svenson, bishop of Skalholt, speaks of the Great Geyser, and says it erupted periodically every twenty-four hours. Since his time a great deal has been written concerning the geysers and hot springs of Iceland, as a reference to the bibliography appended to this report will show.

In the Haukadal locality there are three principal geysers, viz, the Great Geyser, Strokhr or Stroekr, and the Little Geyser or Roarer.

The Great Geyser.—This is the most noted geyser of the world, not only because of the height to which it spouts and the magnificence of the display, but also because it was for a long time the only geyser‡ known to exist, and it was therefore carefully studied by scientific men, and has been made the object of many trips to Iceland.

It is situated at the northern end of a plateau of deposits at the foot of Laugerfial or Laugafjall, an igneous hill of 300 or 400 feet height, and consists of a bowl or basin, compared by Sir J. Hooker to a saucer with a hole in it, on the summit of a mound of siliceous deposit, above which it rises to the height of 7 feet. The entire mound on the west side is 15 to 20 feet high, and on the east 25 or 30 feet, the slope here being very gradual. On the northwest and south sides the slopes are abrupt. It is about 200 feet in diameter, and the cauliflower-like deposit is arranged in circular steps. The basin is not quite circular, having, according to most observers, an indentation on one side. As will be seen from a table given a little farther on, the measurements of the basin and tube are variously given by the different observers; 46 by 56

* On the map in Mr. John Coles' book (Summer Travelling in Iceland, &c., London, 1882) about 50 springs are shown, the space in which they are included measuring about 1,600 by 500 feet.

† Iceland, &c., vol. i, by Ebenezer Henderson, p. 61.

‡ Geyser, Geysar, Geiser, or Geisir is an old Icelandic word, meaning gusher or rager, and is derived from the verb geysa or gjosa, to gush, to rage, or to burst forth, to be impelled. In Iceland, in native usage, it is a proper name, being applied not only to the Great Geyser, but also to another fountain at Reykium. The word, however, has become an appellative or common name for the whole class of boiling fountains that spout hot water intermittently, just as the term volcano is derived from the name of one of the vents in the Lipari Islands.

FIG. 13.—Eruption of Great Geyser and Strokhr in Iceland, as seen by Henderson in 1815.

feet is the most common measurement.* When the geyser is not in action the water over the tube in the center of the basin is in constant motion, the hot water rising from the tube constantly displacing the cold water, as proved by Paijkull, who threw bits of paper into the basin and thus indicated that the water after rising was driven slowly towards the edges, when it sank and flowed back along the bottom of the basin. From this one would naturally expect to find the temperature in the basin a shifting one, not only as regards the different parts of the basin, but also as regards the times of observation when compared with the times of eruptions, and such is found to be the case when the different temperature observations are compared. This accounts also for the differences between different observers. The steam from the geyser has a slight odor of sulphureted hydrogen, and the water also has a slight taste of the same gas, but it soon passes off.

There are two kinds of eruption in the Great Geyser (in which respect it resembles a number of our own geysers, especially the Union in the Shoshone Basin, and the Castle and Giant in the upper basin of Fire-Hole River). After the minor eruptions the water does not sink, although they are preceded by the same subterranean explosions as the great eruptions.

According to Descloizeaux, detonations, accompanied with upliftings of two or three feet, occur regularly every hour and a half to two hours, becoming stronger and more frequent as an eruption is approached. Bunsen calls these upheavals "conical water hills." The eruption consists of a succession of jets following each other at short intervals, each consecutive jet attaining a greater height than the previous one, until the maximum is attained at the end. The column is fountain-shaped at the top. After the eruption is over, the water disappears from the basin and sinks about 10 feet in the tube, and does not resume its old level for from two to seven hours.

As to the interval between the eruptions the data are meager. The following table gives the different observations:

Authority.	Date.	Interval or period of eruptions.
Svenson, bishop of Skalholt	Middle of seventeenth century	Once in 24 hours.
Olafsen & Povelsen	Middle of eighteenth century	3 or 4 times in 24 hours.
Ohlsen	1804	Every 6 hours.
Hooker	1809	Once in 30 hours.
McKenzie	1810	
Burton	1814	11 times daily.
Henderson	1816	Every 6 hours.
Krug Von Nidda	1833	24 to 30 hours.
Descloizeaux	1846	11 to 30 hours.
Burton	1872	Every 6 hours.

From this it would appear that the most common interval is about thirty hours. According to Paijkull, the natives state that weeks often elapse between eruptions, and sometimes several eruptions will occur in one day.

* Mr. John Coles, *loc cit*, p. 23, who visited the geyser in 1881, says the cone rises 12 feet above the surrounding level, and measures 101 by 75 yards at the base, and that the basin on the summit measures 56 by 49 feet. In "Frost and Fire" a section of the Great Geyser shows that at a depth of 45 feet there is a ledge from beneath which the stream appears to come.

. As to the duration of the eruptions there is more unanimity, as the following shows:

Duration of eruptions.	Observer.	Date.
8 to 10 minutes or 15 to 18 minutes	Stanley	1789
5 to 8 minutes	Henderson	1815
10 minutes	Dillon	1834–'35
5 to 7 minutes	Descloizeaux	1846
8 to 10 minutes	Allen	1855
7 to 8 minutes	Dufferin	1856
20 minutes	Symington	1859
10 minutes	J. Ross Browne	1867

The following is the description of an eruption by S. Baring-Gould:

Five strokes underground were the signal, then an overflow, wetting every side of the mound. Presently a dome of water rose in the center of the basin and fell again, immediately to be followed by a fresh bell, which sprang into the air full forty feet high, accompanied by a roaring burst of steam. Instantly the fountain began to play with the utmost violence; a column rushed up to the height of ninety or one hundred feet against the gray night sky, with mighty volumes of white steam-cloud rolling about it, and swept off by the breeze to fall in torrents of hot rain. Jets and lines of water tore their way through the cloud, or leaped high above its domed mass. The earth trembled and throbbed during the explosion, then the column sank, started up again, dropped once more, and seemed to be sucked back into earth.

A. J. Symington * describes his experience of an eruption of the Great Geyser as follows:

Subterranean noises, like thunder, were waxing louder and louder, each earth-shock accompanied by a tremor of the ground, more or less violent, but quite unmistakable. Bells of water in quick succession were rising from the basin and falling again, ever increasing in size, till a large one burst; and then jets of water in successive spurts rushed up in sheafs from the tube; at first about 10 feet, then the height was 15, 20, 30, 50 feet, and so on, each effort surpassing the preceding, till it attained the height of 200 feet. The fountain did not fall down between each jet, but, nearly holding the elevation once gained, the whole grew up bodily by a series of jerks, each higher than the last. Dense clouds of steam enveloped the whole, and only afforded occasional glimpses of the columns of water from the leeward side. White vapor also spread out above the fountain, rolling away in vast curling volumes, which, condensing in the air, came down like heavy dew. Tremendous sounds were continuously heard, like the roaring of an angry sea broken in upon by the near discharge of minute guns. It is at last what we longed to behold, a grand eruption of the Great Geyser! The vast body of water from the central pipe continued jetting up, till, as I have said, it attained the height of 200 feet, falling down again into the basin, which was brim full to overflowing. The subterranean rumbling sounds and reports, accompanied with vibration of the ground, were fearful. Jets of water rushed up in sheaf with a continuous noise, such as would be produced by 500 rockets discharged into the air at the same instant.

Even the beautiful clouds of steam which robed the geyser were regarded by us with an indescribable feeling of mysterious awe and wonder, as if we had actually discovered the fabled magic vapor, from which the Eastern Ufret or any other vision might arise; while the sharp tinkling plash of the descending water could at times be heard amidst the loud, hissing, roaring, booming, and confused Babel of all unearthly sounds. The eruptive forces having now expended themselves for a time, the fountain gradually subsided, in the same manner though more speedily than it had risen. The whole terrific spectacle lasted about twenty minutes. We were singularly fortunate, as, from what we were told, few eruptions of late have lasted more than four or five minutes, or attained half the height of this which we had just witnessed.

* In Pen and Pencil Sketches of Faroe and Iceland, 1862.

The following table will show at a glance the various observations that have been made upon the Great Geyser:

Table of observations on the Great Geyser of Iceland.

Date of observations.	Name of observer.	Size of basin.	Depth of basin.	Size of tube.		Temperature in degrees.	Height of column of water.
				Diameter.	Depth.		
		Feet.	*Ft. in.*	*Feet.*	*Feet.*	°*F.*	*Feet.*
1770–1772	Olafsen and Povelson	Diam., 57			72		360*
1772	Banks						6–92
1772	Von Troil	Diam., 59	9 1				92†
1783	Banks and Solander						
1789	Sir John Stanley	Diam., 60	8	8½	70	180–200	96*m*
1804	Lieutenant Ohlsen						212*m*
1809	Hooker						100‡
1810	Sir George McKenzie	46 by 56	3	10	60	209	90
1815	Henderson	46 by 56	4	8–10	78	183–203	150
1833	Krug Von Nidda					194	90
1834	Barrow	52 by 56	4	10–12	67–70	180–190	80
1834–1835	Dillon	46 by 56	3	12			40
1836	French expedition	52½		16	75½		105*m*
1840	M. Robert					219§	
1845	Madam Pfeiffer						100
1846	Bunsen				66	185.4	140–177*m*
1846	Descloizeaux					185	162*m*
1852	Pliny Miles					209	70–75
1855	Robert Chambers	Diam., 72	4	10	83	188	
1855	Robert Allen	72.6 by 68.1	4	10	83.2		
1856	Lord Dufferin						60–70
1859	Symington						200
1860	Forbes						70–80
1863	Baring Gould						90–100
1864	Bryson						(‡)
1864	Robert McKay Smith						100*m*
1865	Paijkull					194	
1867	J. Ross Browne						60
1874	Samuel Kneeland				70		
1874	Bayard Taylor	Diam., 30			85		120
1874‖	Walker					187	
1881	John Coles	56 by 49	4	10	78¶	**228	

* This is probably an estimate, although Mr. Robert Allen says that well-informed natives do not consider it at all improbable that such a height could be attained. All the heights marked *m* were actually measured.

† Von Troil says this height was obtained by every member of the party writing down the height as it appeared to him, and then afterwards they chose the medium height.

‡ As high as Scott monument.

§ This temperature is at the depth of 30 feet. At 60 feet he got a temperature of 255° F.

‖ Prof. C G. Rockwood, in Vol. XII, Amer. Jour. Sci. and Arts, 1877, p. 25, says that since the eruptions of December, 1874, and January, 1875, the geysers have dried up and give out only hot smoke and ashes. If this be so, it is another proof of the connection of volcanic action and thermal springs.

¶ The discrepancies in this column are probably due to the fact that some of the observers include the depth of the basin with the depth of tube.

** This temperature was at the bottom of the tube. It would appear that the geyser had come to life again, although Mr. Coles did not see it in action. Just before he was there, however, it had spouted 100 feet or more, and was very active.

Strokhr or *Strockr** was first described by Sir John Stanley, who called it the New Geyser. Before 1789 it was an inconsiderable spring, the name then being applied to another geyser called by Stanley "The Roaring Geyser." The latter has since become a quiet spring.

Strokhr is about 120 yards from the Great Geyser. It has no basin like the latter, but gradually narrows from a diameter of 9 feet at the surface to 10 inches at 27 feet below the surface. There is a wall or rim on one side, which is about a foot and a half in height. The other side is level. In the funnel-shaped tube the water is usually from 9 to 10 feet below the surface. The temperature does not change much, being at or near the boiling point nearly all the time. It is in a state of con-

* *Strockr* is derived from the Icelandic verb strocka, to agitate, to bring into motion, and means a churn.

stant ebullition, except just before an eruption, which begins without any other premonitory symptoms or detonations, as in the case of the Great Geyser. The jets during the eruptions are lanceolate, and follow each other rapidly. Eruptions can be brought on by stopping up the tube with clods of earth and stones. This stopping of the tube hinders the disengagement of the steam and increases the pressure, which at last suddenly removes the impediment.

The following is a description of an eruption by Henderson, who saw it in action in 1814:

> It is scarcely possible, however, to give any idea of the brilliancy and grandeur of the scene which caught my eye on drawing aside the curtain of my tent. * * * A column of water, accompanied with prodigious volumes of steam, was erupted with inconceivable force and a tremendously roaring noise to varied heights of from 50 to 80 feet, and threatened to darken the horizon, though brightly illumined by the morning sun. * * * At length I repaired to the fountain, where we all met and communicated to each other our mutual and enraptured feelings of wonder and admiration. The jets of water now subsided, but their place was occupied by the spray and steam, which, having free room to play, rushed with a deafening roar to a height little inferior to that of the water. * * * After continuing to roar about half an hour longer the column of spray visibly diminished and sank gradually till twenty-six minutes past six (it began at twenty-three minutes past five), when it fell to the same state in which we had observed it the preceding day, the water boiling at the depth of about 20 feet below the orifice of the shaft.

From this description it is evident that Strokhr has a steam period of considerable length, in which it is very much like a number of the geysers in the Yellowstone National Park.

In the following table are compiled the observations of different observers. So much time has always been devoted to the examination of the Great Geyser that Strokhr has often been neglected.

Table of observations on Strokhr Geyser.

Date of observations.	Observer.	Size of tube.		Height of column erupted.	Interval or period.	Duration of eruption.
		Diameter.	Depth.			
			Feet.	*Feet.*		
1789	Sir John Stanley	6 feet 10 inches.		132		
1809	Sir J. W. Hooker			60	Every 10 or 12 hours.	
1810	Sir George McKenzie			70		Half hour.
1814–'15	Ebenezer Henderson	9 feet	44	50 to 80		Water period over 15 minutes; whole eruption ¾ to 1 hour.
1834–'35	Dillon			120		35 minutes.
1836	French expedition	8 feet	65	92		
1846	Bunsen	7 feet	43	160		
1846	Descloizeaux		42	162	6 hours	
1855	Robert Allen	Under 9 feet.	87½	90–100		
1855	Robert Chambers	9 feet	57			
1856	Lord Dufferin			40		
1861	Rev. Fred. Metcalf	6 feet	48			
1865	C. W. Paijkull					Lasted 2 hours.
1867	J. Ross Browne			60 or 70		
1874	Bayard Taylor			120		
1881	John Coles	10 feet	42			

Little Geyser and *Roarer*.—The Little Geyser spouts only from 10 to 20 feet about every two hours. Its basin or bowl is about 12 feet in diameter, and very handsomely ornamented. The pipe leading downward from the basin is very irregular, having a depth of 38 feet and diameter of 3 feet.

The Roarer, which previous to 1789 was called Strokhr, once rivaled the Great Geyser in the magnificence of its displays, but after the earthquake of that year gradually diminished, and finally ceased to spout.

Mud Springs.—Besides the geysers and simple thermal springs, Iceland has the same kind of mud springs that are seen in the Yellowstone National Park and in New Zealand. S. Baring Gould, in his "Iceland," gives a graphic description as follows:

Picture to yourself a plain of mud, the wash from the hills, bounded by a lava field; the mountains steaming to their very tops, and depositing sulphur, the primrose hue of which gives extraordinary brightness to the landscape. From the plain vast clouds of steam rise into the air, and roll in heavy whorls before the wind, whilst a low drumming sound proceeding from them tells of the fearful agencies at work. * * * It is not pleasant walking over the mud; you feel that only a thin crust separates you from the scalding matter below, which is relieving itself at the steaming vents. These vents are in great numbers, but there are especially twelve large caldrons in which the slime is boiling. In some the mud is thick as treacle; in others, it is simply ink-black water. The thundering and throbbing of these boilers, the thud-thud of the hot waves chafing their barriers; the hissing and spluttering of the smaller fumaroles, the plop-plop of the little mud pools, and above all the scream of a steam whistle at the edge of a blue slime pool, produce an effect truly horrible. In some of the caldrons the mud is boiling furiously, sending sundry squirts into the air; in others bells of black filth rise and explode into scalding sprinklings; in one a foaming curd forms on the fluid, and the whole mass palpitates gently for a moment, then throbs violently, surges up the well, and bursts into a frenzied, roaring pool of slush, squirting, reeling, whirling in paroxysms against the crumbling sides, which melt like butter before its fury. One or two of the springs have heaped themselves up mounds around their orifices; others, however, gape in the surface without warning; and the steam is so dense, and the sulphurous fumes so suffocating, that one becomes bewildered and can hardly pick one's way among them.

I have quoted this description somewhat at length, for the phenomena described are so exactly similar to those of the Yellowstone region, that one could almost imagine the writer to be speaking of them, rather than of the Iceland springs.

Before closing this chapter I give a catalogue (as perfect as I can make it with the data at hand) of the thermes of Iceland.

Table of hot springs and geysers of Iceland.

[For authorities used in the preparation of this table or catalogue the reader is referred to Bibliographical Appendix B.]

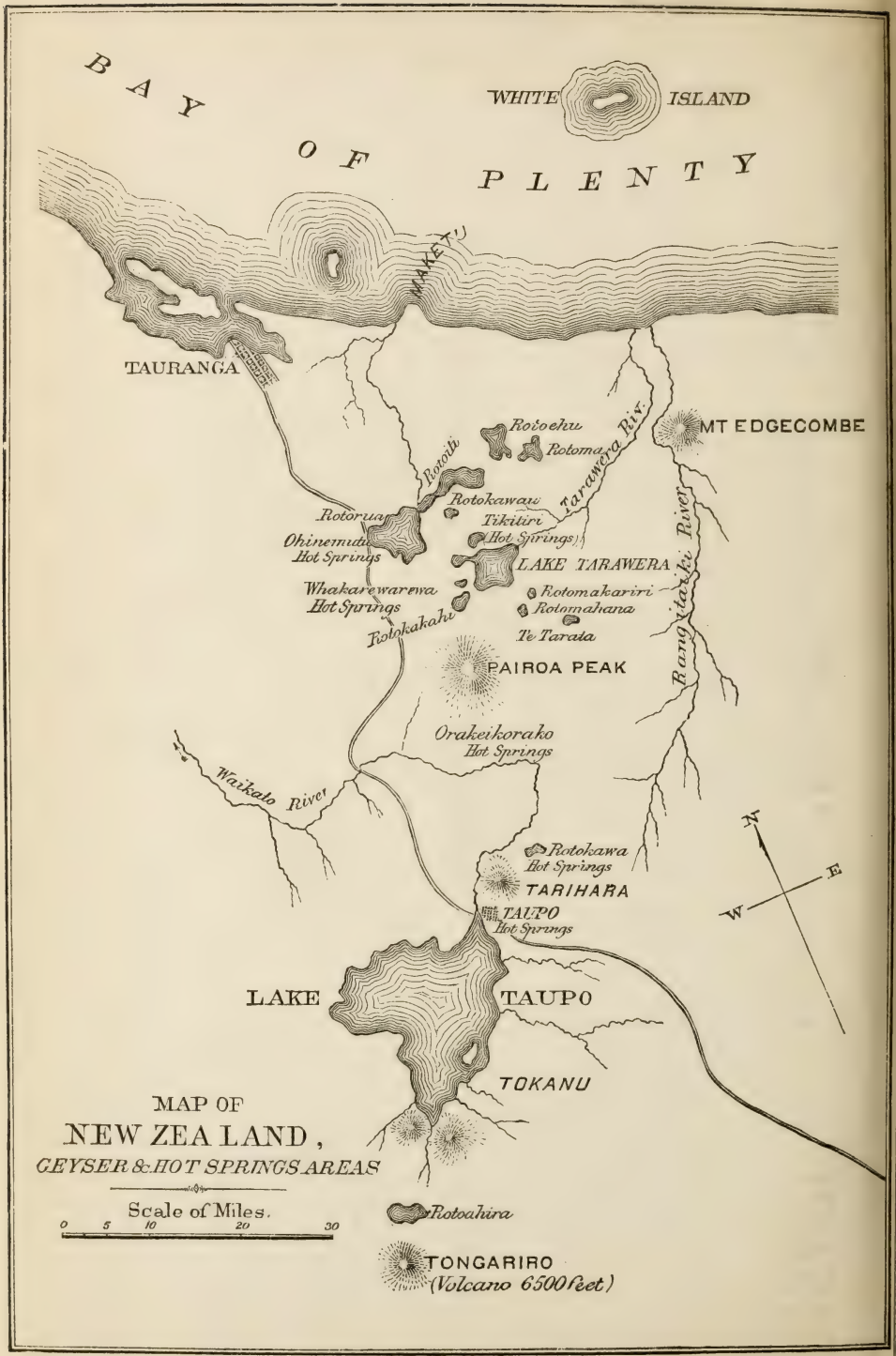
Locality.	No. of springs.	Temperatures.	Names of principal springs.	Remarks.
SOUTHERN AREA.		° *F.*		
Hveravellir	12	.....	Auscrholinn (Roaring Mount).	There are, besides the twelve principal springs, numerous steam vents, solfaterras and salses, and ancient deposits.
Haukadal	100	180–209	Great Geyser, Strokhr, Little Geyser, Roarer, Blesi.	This is the geyser region of Iceland par excellence. For description see preceding pages.
Reykialaug, 6 miles from Holum, north of Haukadal.	3	104 114 124	.....	These are small springs, with no incrustations nor peculiar taste.
Laugarvalla (southeast from Haukadal).	.....	212	Reykia-hver, Laugar..	There are numerous spouting springs and caldrons scattered over considerable area. Reykia-hver is 7 miles to the northeast of the lake, near which most of the springs are situated.
North of Laugarvalla, Yfri Reykium, Sydri Reykium.	3	.....	.....	The first is small; the other spouts to the height of 12 feet, lasting 20 seconds; the third is a small boiling spring.

Table of hot springs and geysers of Iceland—Continued.

Locality.	No. of springs.	Temperatures.	Names of principal springs.	Remarks.
SOUTHERN AREA—Con.				
Reykium (south of east from Reykiavik, the capital of Iceland).	100	.....	Geyser, Badstofa, Akkra-hverar, Seyder (Boiler).	The geyser has been described in the preceding pages. The Badstofa is near the river, and spouts to the height of 20 feet, the action lasting 10 minutes. Akkra-hverar are two remarkably large springs in a large assemblage of springs on the south side of the river. Seyder is a boiler, one of a number of vapor springs.
Krisuvik (south of Reykiavik).	.....	.....	.....	Mud springs, sulphur springs, and steam vents.
Reykiadal (Valley of Smoke, near Reykholt).	26+	.....	Sturlu-reykia-hverar, Hunda-hver, Tungu-hverar, Ar-hver (River Spring), Scribla.	The principal spring at this locality, which is two miles from Reykholt, has three apertures, and resembles a steam-engine. The eruptions continue a minute, at intervals of 15 seconds. Hunda-hver is connected with the spring above, but is not of much account. The Tungu-hverar are about a mile below the other springs, and consist of some sixteen boiling springs. The river spring, with three orifices, is on the summit of a small rock in the river. There are other springs in the water of the river. Scribla is a hot, spouting fountain in a morass, amid other hot springs.
Staffholt (westward from Reykholt).	6	.....	.....	Generally small springs that spout a foot or so. They have no extensive deposits.
WESTERN AREA.				
Lysuhol	1	90	.....	Has beautiful petrifactions.
Svinadal	.....	.....	.....	Unimportant.
Reykiaholar	.....	.....	Krablanda	There are numerous springs at this place. Krablanda spouts to a height of 3 or 4 feet for 5 minutes, with an interval of 5 minutes, boiling between eruptions.
In Breidafiord	.....	.....	.....	Several springs in the sea and on rocks; some exposed only at low water.
EASTERN AREA.				
Reykiahlid	.....	144	.....	Vapor bath here in the midst of steam vents and solfaterras.
Volcano of Askja	.....	Hot	.....	No particulars given by Lock, who mentions them in Proc. R. Geogr. Soc., 1881, p. 471, vol. iii.
Mount Krabla	.....	.....	Krabla or Kafla	This is a pool 300 feet in circumference, spouting 30 feet every 5 minutes, lasting 2½ minutes, as seen by Henderson; but in 1863, Baring Gould says it was a cool, green pool. There is a multitude of salses and sulphur springs near here.
Reykiahverf (northwest from Greniadarstad.)	6+	182*	Nordur-hver, Oxa-hver, Sydster-hver.	Nordur-hver has a basin 34½ feet by 33 feet, and a pipe 14 to 15 feet deep and 10 feet in diameter; very irregular; it boils and spouts. Oxa-hver is an oblong pipe, 8 feet in diameter, and spouts every 5 or 6 minutes, 15 or 20 feet, lasting 1 minute. Sydster-hver has three openings; the largest spouts 6 feet for 2 minutes; one is quiet, and the smallest one throws three oblique jets, which alternate with each other.

* And higher.

NOTE.—*Hver*, in Icelandic, means a large kettle, and is the general term for boiling springs or fountains. *Laug* is a bath, and *Reykir*, one that sends up clouds of steam. *Náma* is a pit of boiling mud.


BAY OF PLENTY
WHITE ISLAND
MAKETU
TAURANGA
Rotoehu
Rotoma
Tarawera Riv.
MT EDGECOMBE
Rotoiti
Rotokawau
Tikitiri
Hot Springs
Rotorua
Ohinemutu
Hot Springs
LAKE TARAWERA
Whakarewarewa
Hot Springs
Rotomakariri
Rotomahana
Te Tarata
Rotokakahi
PAIROA PEAK
Rangitaiki River
Orakeikorako
Hot Springs
Waikato River
N
E
W
Rotokawa
Hot Springs
TARIHARA
TAUPO
Hot Springs
LAKE TAUPO
TOKANU
MAP OF
NEW ZEA LAND,
GEYSER & HOT SPRINGS AREAS
Scale of Miles.
0 5 10 20 30
Rotoahira
TONGARIRO
(Volcano 6500 feet)

CHAPTER II.

THERMAL SPRINGS AND GEYSERS OF NEW ZEALAND.

The wonderful hot springs and geysers of New Zealand are situated on the North Island, and may be divided into six groups, which are scattered through the area that extends from Tongariro (a semi-active volcanic cone), in about the center of the island, to the Bay of Plenty.* This is a distance of about 100 miles, the direction northeast and southwest. White Island, which is the seat of springs also, is about 30 miles out at sea, and is on the same line of volcanic activity. In this area three parallel lines of springs may be traced. The first is the most eastern, and extends from Tongariro through the eastern part of Lake Taupo to Whakaari, or White Island, which is, as already stated, about 30 miles from the main land. On this line are the springs of Lake Taupo, Mount Kakaramea, and those of Rotomahana.

The second, or middle line, is much shorter, and comprises the springs of Orakeikorako and the Pairoa Range.

The third or western line, includes the springs of Rotorua and Rotoiti. Motu Horu (White Island), which is said to have hot springs, is in the Bay of Plenty, four miles from shore, and may be considered an extension of this line.†

Tongariro rises 6,500 feet above sea level, and Lake Taupo is 1,250 feet above the sea. Lake Tarawera is 1,075 feet above the sea, and Rotorua 1,043 feet. The rocks of the region are all volcanic trachytes—obsidean and tuffs prevailing. At Lake Taupo they are probably rhyolitic, for Hochstetter calls them "Quartzous trachytic lavas."

A noticeable feature of the region is the presence of so many lakes. At the south end are Lake Taupo, 20 by 25 miles wide, and two small lakes named Rotoahira and Rotokawa (Bitter Lake). About 40 miles northeast of Lake Taupo, is an area of about 240 square miles. There are sixteen lakes of which the following are the principal ones, with their sizes and translations of names, as far as can be given:

Lake Tarawera (Burnt Cliffs), 5 miles by 7 miles.
Rotorua (Hole Lake), 6 miles in diameter.
Rotoiti (Little Lake), 7 miles by 1 to 2 miles.
Rotehu (Nose Lake), 3 miles by 1½ miles.
Rotoma.
Rotokawau.
Tikitapu Lake, 1 mile long.
Roto Kakahi (Muscle Lake).
Okatairia.
Okareka, 6 miles circumference.
Rotomakariri (Cold Lake).
Rotomahana (Warm Lake), 1 mile by 1¼ miles.

* There are a few other hot spring localities in New Zealand which do not deserve especial mention here, and for the temperatures of which the reader is referred to the table of springs in Chapter VII. With the exception of two localities in the South Island, they are in the North Island, at the northern end, near the Bay of Islands.

† In 1881 the General Assembly or Parliament of New Zealand passed an act called "The Thermal Springs Districts act of 1881," for the regulation of the areas in which hot springs occur; and under this act two districts were incorporated, viz: the Taupo District, and the Rotorua or Lake District. Medical officers were appointed, hospitals erected, and surveys made, so that lots can be leased. All mineral waters, hot springs, and streams, however, remain vested in the crown.—(See *New Zealand Thermal Springs District, &c., Wellington, New Zealand*, 1882.)

As to the age of the springs and geysers there are, as far as can be learned, no traditions among the natives. The volcanoes have not been active within the range of their traditions, and they are probably of Tertiary age, although not yet quite dormant. Light earthquakes are frequent in the region near Tongariro. Ngauruhue, a crater 6,500 feet high, close to Tongariro, is at present a solfatara, and on the west slope of Tongariro, 1,800 feet above Rotoahira, is a geyser which is said to be active only during the time western winds prevail. I will now give brief descriptions of the various localities, premising that the catalogue following the description will give additional data as to temperatures, number of springs, &c.

LAKE TAUPO AREA.

Lake Taupo, as we have mentioned above, is 25 miles long and 20 miles wide in the widest part. Its water is transparent and of a bright green tint. The main road from Napier to Auckland, over which coaches are run, passes one of the northern bays of the lake, so that access to the springs is not difficult. The latter are found both at the north and south ends of the lake. For a whole mile at the former the water steams along the shore. Near Taupo (or Tapuaeharuru on some maps), a town or township at this end of the lake, the government controls a number of active springs and bathing pools; and some provision has been made for the comfort of visitors, both by the government and by private parties. The springs near Taupo, or Tapuaeharuru, may be divided into four groups: 1st. Two miles from Tapuaeharuru the Crow's Nest and MacMurray's Bath are the important springs. 2d. One-half mile east of the Waikato River, where artificial baths have been erected. 3d. A mile and a half from the town along the east shore of the lake and back from the lake. 4th. Otumheka Valley. The springs are boiling and at all temperatures below the boiling point, and there are solfataras and fumaroles of all sizes, sulphur and silica being the principal deposits. The principal spring here is the Crow's Nest, which spouts 10 to 15 feet occasionally. At the south end of the lake the northern slopes of Kakaramea Mountain are full of steam holes, called by the natives *hipaoa*—the chimneys. Some of the springs here are chalybeate. Tokanu, or Tokaano, a native village, with numerous springs or puias, is also at this end of the lake. About 30 miles south of Lake Taupo, at the head of the Waikato River, in the Onetapu desert, there is a spring (one of many) issuing from the base of Ruapehu. This might be called the Tongariro district.

About 10 miles northeast of Taupo is Rotokawa, the springs of which are described by Josiah Martin* as follows:

> Rotokawa is a small acid lake in this district [Taupo district] which is approached with extreme caution because of the treacherous nature of the deposits of tufa, obsidian, and pumice, which are broken through by so many hissing jets that, as the soil reverberates to our tread, and the guide repeats his warnings, we confess to a feeling of insecurity, painfully enforced by various reports of unwary wanderers who have fallen through. The ground is insufferably hot to the touch, and here and there we discover yawning chasms of black, seething mud, from which the vapors of sulphureted hydrogen, mingled with the fumes of sulphurous acid, greatly offend our senses, and painfully remind one of the visionary Gehenna and of its traditional terrors.

ROTOMAHANA AREA.

Rotomahana, or Warm Lake, is about 35 miles northeast of Lake Taupo, and is the locality of the famous Te Tarata. The water of the

*The Geysers, Hot Springs, and Terraces of New Zealand. Popular Science Review, London, No. 12, p. 369.

FIG. 14.—View of cold-water basins of Te Tarata, at Rotomahana, New Zealand.

lake is of a dull green color, saline in all parts, except one corner, and of varying temperatures. In some places it is as high as 100° F. In the center is an island called Puia, filled with springs and steam vents.

On the eastern side are three areas of siliceous sinter. At the head of the northern is Te Tarata, which is some 250 yards back from the edge of the lake, and 80 feet above it. South of this is another terrace, with Rotopunamu, or Green Lake, at its head. This is about 300 yards from the lake, and 100 feet above it. The siliceous deposits extend from it in a southwesterly direction to the lake, with an average width of about 100 yards. Between the foot of this terrace, which has numerous springs scattered over it, and the foot of Te Tarata there is a narrow strip of deposits with springs. At the foot of the terrace it is joined by a third, more southern siliceous terrace, at the head of which are Ngawhaua, Koingo, and Whatapoho. This mass is about 150 yards wide, and extends back from the shore of the lake about 200 yards at the greatest distance. The top is 100 feet above the lake. The hill on the slope of which these deposits are located, slopes on the southwest into Rotomahana, and on the northeast to Rotomakari (Cold Lake), and old craters may be found on its sides, and the surface is warm, and the soil insecure and treacherous.

Otakapuarangi, the Pink Terrace, is on the opposite side of the lake. Besides these areas there are a couple of others which will be noted in the accompanying table.

Te Tarata (*tattooed rock or stone*).—The siliceous deposits at the head of which is the basin of the world-renowned spring, occupy a space of over three acres. There is an upper plateau or platform, below which the deposit is in three sections, viz, a central mass of two wings separated from each other by clusters of foliage growing upon natural soil. Below these, however, the deposits are again united. The central section is the oldest, and has overhanging buttresses and terraces rising tier above tier. The right wing is an irregular slope broken into steps at several points, without any regular basins, and the left wing, over which the most recent overflow finds its way, is much like the right wing. Ridges and slopes, rather than basins and terraces are formed. The following is Hochstetter's description of Te Tarata.

About 80 feet above the lake, on the fern-clad slope of a hill, from which in various places hot vapors are escaping, there lies the immense boiling caldron in a crater-like excavation, with steep reddish sides 30 to 40 feet high, and open only on the lake side toward the west. The basin of the spring is about 80 feet long and 60 wide, and filled to the brim with perfectly clear, transparent water, which in the snow-white incrusted basin appears of a beautiful color like the blue turquoise. At the margin of the basin I found a temperature of 183° F., but in the middle, where the water is in a constant state of ebullition to the height of several feet, it probably reaches the boiling-point. Immense clouds of steam, reflecting the beautiful blue of the basin, curl up, generally obstructing the view of the whole surface of water; but the noise of boiling and seething is always distinctly audible. The reaction of the water is neutral; it has a slight salty, but by no means unpleasant, taste, and possesses in a high degree petrifying, or rather incrusting, qualities. The deposit of the water is like that of the Iceland springs, siliceous, not calcareous, and the siliceous deposits and the incrustations of the constantly overflowing water have formed on the slope of the hill a system of terraces, which, as white as if cut from marble, present an aspect which no description or illustration is able to represent. It has the appearance of a cataract plunging over natural shelves, which, as it falls, is suddenly turned into stone.

The flat, spreading foot of the terraces extends far into the lake. There the terraces commence with low shelves containing shallow water-basins. The farther up, the higher grow the terraces; two, three, also some four and six feet high. They are formed by a number of semicircular stages, of which, however, not two are of the same height. Each of these stages has a small raised margin, from which slender stalactites are hanging down upon the lower stage; and encircles on its platform one or more basins resplendent with the most beautiful blue water. These small water-

basins represent as many natural bathing-basins, which the most refined luxury could not have prepared in a more splendid and commodious style. The basins can be chosen shallow or deep, large or small, and of every variety of temperature, as the basins upon the higher stages, nearer to the main basin, contain warmer water than those upon the lower ones. Some of the basins are so large and so deep that one can easily swim about in them. In ascending the steps, it is, of course, necessary to wade in the tepid water, which spreads beside the lower basins upon the platform of the stages, but rarely reaching above the ankle. During violent water-eruptions from the main basin, steaming cascades may occur; at ordinary times but very little water ripples over the terraces; and only the principal discharge on the south side forms a hot, steaming fall. After reaching the highest terrace there is an extensive platform, with a number of basins, 5 to 6 feet deep, their water showing a temperature of 90° F. to 110° F. In the middle of this platform there arises, close to the brink of the main basin, a kind of rock island, about twelve feet high, decked with manuka, mosses, lycopodium, and fern. It may be visited without danger, and from it the curious traveler has a fair and full view into the blue, boiling, and steaming caldron. Such is the famous Te Tarata.

This geyser usually boils to a height of 10 or 15 feet. When there is a south wind, according to Mair,* the water recedes, and when the wind changes the basin refills at the rate of three or four feet per hour, boiling and roaring like an engine, and when almost full sends up a column of water 20 feet in diameter to a height of 60 feet.

Otakapuarangi (*cloudy atmosphere*) or the *Pink Terrace* is on the opposite side of the lake from Te Tarata, which it much resembles, except that its 50 terraces are tinged with pink, which is most marked in the upper portions of the deposit. The rocks on the hill surrounding the siliceous mass are harder than those around Te Tarata. The main platform upon which the basin of the geyser is situated is 60 feet above the lake and measures 100 yards by 100 yards. The geyser is smaller than that of Te Tarata, measuring about 50 feet diameter, and is very deep, filled with azure-tinted water which is generally boiling, and has a temperature of 204° to 208° F. At times the geyser quiets and the overflow ceases, but the times of these cessations have never been determined. The pink color is due to iron oxide, traces of which are found upon analysis of the water. Unlike Te Tarata, the deposits are narrower at the bottom near the lake, on account of being inclosed in a horseshoe curve of the hill.

WHAKAARI, OR WHITE ISLAND.

White Island is about 30 miles from the main land, in the Bay of Plenty, and is the summit of a submerged volcanic cone which is now in the condition of a solfatara. According to Dr. Hector the area covered with siliceous sinter is a flat of about 30 acres, 60 feet above sea-level, in which there is an acid hot geyser-lake (Lake Hope), which covers a space of 15 acres. Its temperature is 110° F. From one part of this lake the water spouts to the height of 100 feet. There are mud holes surrounding the lake, and calcareous sulphates are found among the deposits, the sea-water making the difference in the deposits, and, according to Hector, marking a third class of springs not found in the Iceland classification.

ORAKEIKORAKO AREA.

The Orakeikorako springs are about 20 miles from Taupo, on the Waikato River. The most remarkable springs are on a large whitish mass of siliceous deposits, 120 yards long and of about the same number of feet in width. It is called the flat stone by the natives. Seventy-

*New Zealand Institute Transactions, Vol. IX, 1876.

FIG. 15—Otakapuarangi. Pink Terrace at Rotomahana, New Zealand.

six jets of steam or water were counted from one point of view by Dr. Hochstetter. The principal geyser is quite regular, spouting every two hours to a height of 20 to 30 feet, the column having an angle of 70°. The eruptions last two minutes, and the basin refills ten minutes after the eruption is over.

At this locality there is a beautiful cave, known as Alum Cave, in which there is a beautiful blue pool of warm water. The springs extend some distance down the river and consist of mud pots, solfataras, boiling springs, and quiet pools.

PAIROA RANGE AREA.

The springs of this area are from 4 to 16 miles north of Orakeikorako. One is found on the summit of Pairoa peak, whose slopes are covered with mud springs. There are also boiling springs and small gray and pink mud volcanoes. The absence of siliceous deposits around one group is noticeable.

ROTORUA AREA.

Rotorua is an almost circular lake, having a diameter of about 20 miles. It is 1,043 feet above sea-level, and has near its center a volcanic island. The principal springs are found on the west side of the lake at Ohinemutu. The bank of the lake is perforated with springs, and every native hut has its own natural boiler which is used as a kitchen. One curious spring (Kuirua) is strongly alkaline, and is celebrated for its saponaceous properties. It is utilized as a laundry by the settlement. The settlement is upon the lake side of a narrow ridge which is about 30 feet high. On the opposite side are several large ponds, in some of which the water has a temperature of 200° F.

About a mile south of Ohinemutu is Sulphur Point, where there is an extensive plateau of siliceous material upon which there are ponds of all sizes, mud holes, geysers, and bubbling sulphur basins, while sulphur incrustations are abundant everywhere. Many of the springs are noted for their medicinal properties, and one of them is called "Pain Killer." Other springs are found along the lake farther south.

Whakarewarewa is south or southeast of the lake and about 2 miles distant from it. The settlement is on the sides of a chasm in which is a stream lined with fumaroles. There are several siliceous plateaus or mounds upon which are geysers, boiling springs, and mud pots. There are several hundred boiling springs and mud baths and a number of geysers. The famous Wakiti, or Waikite, has a large cone made up of circular terraces, which are 100 feet in diameter at the base, diminishing to 3 feet at the top, which is 15 feet above the level of the plateau. In the summit the opening is funnel-shaped, and usually the water is out of sight, although it is said to throw a column of water to the height of 80 or 100 feet at certain times, which seem to be regulated by the condition of the atmosphere or the direction of the wind. Ordinarily it spouts about 8 feet every eight minutes.

Herbert Meade, R. N., says that about the 20th of December it becomes active, increasing in vigor until February, when it culminates, spouting 40 or 50 feet, and then subsides.

The plateau upon which Parikohuru is situated has a temperature 100° F. The water in this large basin is of a beautiful blue color, and boils constantly. There are near it a number of small geysers that can be started by throwing sod into them. A number of the springs are said to be efficacious in rheumatic and cutaneous diseases.

The Tikitere Springs are on the east side of the lake. Geysers and mud holes are abundant. The largest of the former is 100 feet in diameter, and boils vigorously. Dense clouds of steam rise from all parts of the locality.

The following is the catalogue of the New Zealand springs and geysers. It is impossible to give any correct idea as to the number of springs:

Table of New Zealand springs and geysers.

[For the authorities used in preparing this table the reader is referred to Bibliographical Appendix C.]

Area and locality.	Number of springs.	Names of principal springs and geysers.	Temperatures.	Remarks.
LAKE TAUPO AREA.				
South end of lake.				
			°F.	
North side of Kakaramea Mountain.	.....	.....	125 153 156½	The whole northern side of the mountain seems to have been boiled soft; numerous steam holes exist 500 feet above level of the lake.
West slope of Tongariro	.....	Ketetahi.....	.....	
Near Tokanu (area of 2 square miles).	.....	Pirori (fountain).....	.....	6 to 8 feet diameter; spouts from 10 to 40 feet a column 2 feet in diameter.
		Te Korokoro - otopohinga (Jaws of Tophinga).	.....	Boils continually.
		Te Puia-nui (clear boiling spring) [mud-spring].	186. 8 188	There are 3 basins with siliceous deposits, and the middle one is said to have spouted in April, 1846, to the height of 100 feet.
North end of lake.				
West foot of Mount Tauhara.	.....	Waikore.....	.....	
		Parakiri (skinner)	.....	
		Ruahine	190	
		Crow's Nest.....	200	Geyser cone, 6 or 7 feet high, 6 feet diameter; siliceous deposits 20 feet in diameter; spouts occasionally.
Near Taupo	....	Parkes Spring	60	
		McMurray's Bath	126	
		Te Hukahuka	116	
		Waipakahi	120	
		Tarewera.....	130	
Right bank of Waikato River, 5 miles north of junction of the Puelo.	.....	Ipukaihimarama.....	.....	
		Te Kohaki.....	.....	
Otumaheke Valley.....	.....	Karapite (circular)....	.....	The valley has numerous steam vents and mud holes; Karapite is a steam spring.
Near Rotokawa.....	.....	.....	.....	Steam jets, boiling springs, mud holes, and solfataras.
ROTOMAHANA AREA.				
East and northeast side of Lake Rotomahana.	75 to 100	Te Tarata (tattooed rocks).	183 to 214	A complete description has been given in preceding pages.
		Great Ngahapu.....	210	This is 10 feet above the lake and is 30 feet by 40 feet; has clear water in active ebullition; rises 8 to 10 feet; quiet at short intervals, and has siliceous deposit.
		Little Ngahapu.....	.....	Has turbid muddy water.
		Te Takapo.....	206	Has a siliceous basin 8 by 10 feet; spouts 30 to 40 feet.
		Rotopunamu (Green Lake).	63	Is 100 feet above the lake and is 40 feet in diameter; is beautifully green, and blue on the edge.
		Ruakiwi (Kiwi Hole)..	210	Measures 12 feet by 16 feet.
		Te Kapiti.....	.....	On the lake shore.
		Ngawhana.....	.....	Quiet hot-water basin.
		Koingo (Sighing Geyser).	.....	Is 100 feet above the lake; 5 by 9 feet, with siliceous deposits; bubbles 3 or 4 feet.
		Whatapoho.....	.....	Shows to a considerable height at times.

New Zealand springs and geysers—Continued.

Area and locality.	Number of spring.	Names of principal springs and geysers.	Temperatures.	Remarks.
ROTOMAHANA AREA—Continued.				
Southeast side		Wakaehu (water in motion).		
		Te Ruahoata		
		Wairake		
		Te Rangipakaru (broken sky).		There are three lagoons.
West side		Otakapuaraangi (cloudy atmosphere). Pink Terraces.	208	See description in preceding pages.
		Cameron's Bath		
		Te Whakataratara		A crater-shaped hole with yellowish-white muddy water.
Northwest side		Atetuhi		
		Te Waiti		
At outlet of lake at north		Teake Manuka		
		Te Mamaku		
		Te Poroporo		
		Tamariwi		
		Te Karaka		
White Island (Whakaari).			110	Mud holes, and a boiling lake that spouts 100 feet at intervals.
ORAKEIKORAKO AREA.				
On Waikato River	76	Puia-Te-Mimi-a'Homai-terangi.	202	Funnel-shaped basin 4 or 5 feet wide; spouts 20 to 30 feet every 2 hours.
		Puia-Orakeikorako	106	Is 30 feet from previous one; has basin 6 by 8 feet; clear bubbling water.
		Alum Cave (main spring).	209	For two years after 1848 it spouted 100 feet.
		(Red mud spring)		14 feet long, 6 to 8 feet wide, and 6 or 8 feet deep.
		Puia Tuhi-tarata		Sky-blue water, and forms a steaming cascade over white, red, and yellow terraces to the river.
		Te-wai-whokata		
		Te Poho		
		Rakau-takuma		
		Wai-mahana		
		Whangairorohea		
		Ohaki		
		Te Wai-angahue		
		Whakapoapoa		
PAIROA RANGE AREA.				
Pairoa Peak		Te Kopiha		Is on the summit of Pairoa Peak; slopes and foot of mountain have mud springs.
Waikite	20			Some clear, some boiling, milky, and mud springs; no siliceous deposits.
ROTORUA AREA.				
Whakarewarewa (near south end of lake).	(*)	Waikite		Has a flat siliceous cone 100 feet in diameter, and 15 feet high; spouts 8 feet every eight minutes, and in February and January reaches 100 feet.
		Turikore	12	
		Pohutu or Pohtu		Has deposits 20 feet high; generally active between 7 and 9 a. m. and 3 to 5 p. m.
		Te Horu		Do.
		Parikohuru		30 feet diameter; boiling.
		Paratiatia (?)		
		Whakaha Rua (bashful geyser).		Is in violent ebullition after dark.
		Koroteoteo (oil bath)	214	The water here is alkaline.
		Medicinal springs	120	
Ohinemutu		Great Waikite		Spouts 12 feet sometimes.
		Perekari	150	
		Little Waikite	201	Has a basin 4 or 5 feet wide; rises several feet every five minutes, and sinks 6 or 7 feet in the interval.
		Te Mimi Okakahi	112	
		Tapui (wind pointer)	190	Has a basin 30 by 50 feet.
		Kuirua [saponaceous spring].	160	Is a pool fed by several hot springs.

*7 or 8 geysers; several hundred springs.

New Zealand springs and geysers—Continued.

Area and locality.	Number of springs.	Names of principal springs and geysers.	Temperatures.	Remarks.
			°F.	
ROTORUA AREA—Contd.		"Pain Killer" [sulphur bath].	204	Is situated in an extensive plateau of sinter.
		Te Kauwhanga [mud bath].	100 or 204	Thick, brown, muddy water with oily slime; offensive odor.
Ohinemutu		Ariku Kapakapa	160	Small pool deposits sulphur, and has a strong outflow; possesses curative properties.
		Sulphur Bay Spring	100	
		Huntini		50 or 60 feet in diameter and spouts 15 feet.
Tikitiri (a valley of solfataras and hot springs on the east side of Lake Rotorua).		Karapo		
		Te Korokoro		
		Te Kuhe (great spring of Tikitiri).	212	Diameter 100 feet; boils furiously, giving off sulphureted hydrogen.
		Te Waikari		
		Te Tarata		
		Harakeke		
		Tihipapa		
		Papa Kiore		
West side of Arikiroa		Ornawhata	185	16 by 6 feet.
Rotoiti		Ruahine	190	Spouts several feet.
		Manuprua	110	

NOTE.—In New Zealand *Puia* is a hot spring, *Papa-puia* springs with clear water and siliceous deposits. *Uku-puia* are boiling mud pools. *Ngawhas* are non-boiling springs or solfataras. *Waiariki* are springs that are suited for bathing purposes.

CHAPTER III.

THERMAL SPRINGS OF THE UNITED STATES.

In this chapter I propose briefly to consider the thermal springs of the United States, other than those of the Yellowstone National Park, which have been described in detail in Part I of this report. The catalogue appended will give as complete a list of the localities as is possible under the circumstances.

The springs are naturally divided into three divisions, viz, those of the Appalachian region, those of Arkansas, and those of the region west of the 105th meridian. In the latter the number of localities is vastly greater, as a single glance at the catalogue will show.

In the Appalachian region the connection of the thermal springs with anticlinal axes and faults was pointed out by Professor Rogers in his geological report on Virginia and in a memoir upon the subject.

In the case of the Arkansas Hot Springs, the Ozark Mountains may be looked to as the cause of their thermal condition, if we accept the idea that the heat of thermal springs is due to mountain corrugation. Between the two regions is the basin of the Mississippi River, in which and on the plains east of the Rocky Mountains there are no hot springs.

In the western area, outside of the Yellowstone National Park, the greatest development of thermal springs is found in the States of California and Nevada, in both of which boiling springs and pseudo-geysers are found associated mainly with eruptive rocks. The deposits of the spring in Ruby Valley, near Ruby Lake, contain 90 per cent. of silica, being true geyserites or siliceous sinters. The deposits at Steamboat Springs are also siliceous. The springs at Salt Lake City, Ogden, and

north of Brigham City, Utah, are on or near the line of faulting of the west side of the Wahsatch Range.

When a comparison of the temperatures is made, the point that attracts attention is the higher range of temperature in the western area. In the Appalachian region the highest temperature is 108°, the majority being below 100°. In the catalogue the temperatures of eighty-five localities in the west, outside of the National Park, are given, and of these sixty-six are 100° or over, and of about the same number of localities of which temperatures are not recorded several are mentioned as being boiling springs. It will be found, also, that the hottest springs are in regions of eruptive rocks.

Only a few of the localities of actual spouting springs will be here briefly described, viz, Steamboat Springs and Volcano Springs, of Nevada, and an area in Southern California, and the geysers of California. The latter is the most noted, and will be described first.

THE GEYSERS OF CALIFORNIA.

The geysers of California are situated in a lateral valley of Napa Valley, called Pluton or Devil's Cañon, in Sonoma County, in Eastern California, north of San Francisco. The cañon is about half a mile in length and about 30 feet wide, and covered with the deposits of extinct springs, among which are numerous steam jets and hot springs, some of which are clear, others turbid, some chalybeate, some sulphurous, and some astringent with alum. The ravine is always filled with the steam which escapes from them. Some of the springs, such as the "Witches' Caldron," are in constant ebullition; others are intermittent, throwing the water in jets, which rise from 2 to 15 or 20 feet. The Witches' Caldron is 7 feet in diameter. The steam-pipe or Steamboat Geyser has an opening 8 inches in diameter, from which the steam ascends to a height of 50 to 100 feet, with a roar like the escape from a steamboat. There are about a hundred springs in all, of which the following are the principal ones:

	Temperature °F.
Black Sulphur Spring	150+
Boiling Black Sulphur Spring	97
White Sulphur Spring, Alum and Iron Spring	
Boiling Alum and Sulphur Spring	150+
Epsom Salts Spring	
Witches' Caldron	195
Medicated Geyser Bath	90+
Steamboat Geyser	
Intermittent Scalding Springs (Geyser)	175
Devil's Inkstand, Alkali Lake, Indian Spring, Boiling Eye-water Spring, Acid Spring	

The steam from some of the springs has been utilized for vapor baths by the construction of sheds over the springs. In Geyser Cañon, a branch of Pluton Creek, the highest temperature, according to Whitney, is 207° F.

STEAMBOAT SPRINGS OF NEVADA.

The Steamboat Springs are in Washoe Valley, east of the Virginia range in Western Nevada. They are described as follows by Mr. Arnold Hague:*

They cover an area about one-quarter or one-third of a mile in length by 800 to 1,000 feet in width. The surface of the ground is covered by a deep accumulation of siliceous sinter, the deposit of the evaporated spring-water. Running lengthwise

* In Vol. II, Descriptive Geology, Geological Exploration of the Fortieth Parallel pp. 825, 826.

with this deposit are a number of parallel fissures or open seams, from two inches up to one foot in width, having a general trend of north 8° west. These fissures are generally continuous, though sometimes filled at intervals with *debris* that has fallen in and choked up the passage. All along the length of these fissures are seen jets and clouds of steam rising; and the sound of water boiling violently may be heard at short distances below the surface, although concealed from view. Where the fissure is perpendicular a depth of 10 or 15 feet may be seen, and in some instances water is at the bottom. In several places the steam issues in puffs, with a noise like that from a steam boiler, and jets of hot water are thrown up, with more or less force, frequently 10 and 20 feet in height; while in other places, the water is raised with just sufficient force to bubble up above the surface and run off. In the whole area there are but one or two small basins where water is at all times standing. In several places there are elevated conical mounds built up by the sinter deposited from the boiling waters. The water flowing from these sources runs away partly over the surface of the deposit, and partly through channels concealed from view a short distance below the surface, and probably finds its way to the Truckee River. The sediment, or rather deposit, from these waters is quite friable, and lies in thin strata; it is occasionally porous and cellular, almost resembling coral. Sulphur occurs, coating the other portions of the deposit. The steam also emits the odor of sulphurous gas.

From this description it will be seen that we have at this locality a repetition on a small scale of some of the phenomena observed in the Yellowstone National Park. The deposit is a true geyserite; the specimens analyzed for Mr. Hague by Mr. R. W. Woodward containing over 92 per cent. of silica.

VOLCANO SPRINGS.

This locality is described by Col. A. S. Evans* as being located in Lander County, Nevada, southeast of Beowawe. Whether it is the same locality as that on Bancroft's map of the Pacific States, south of Argenta I cannot say. Going south, or even southeast, from Beowawe, a station on the Central Pacific Railroad, brings us into Eureka County, and not Lander. I cannot find the locality marked on any map. As there are spouting springs at the locality, I have given below a brief description of them, taken from Colonel Evans' article:

Across the valley, some six miles to the southward, half way up the western slope of a hill, perhaps six hundred feet in height, we saw a long table-land of *mesa*, white upon the top, and with long ribbon-like streaks of blue and white running down thence to the plain below. This had been designated as the locality of the Volcano Springs; but, beyond the discolorations mentioned, there was nothing to attract the attention of a traveler, and one might pass the point a dozen times without being made aware of their existence. * * * Some time before we reached it we heard a noise as of many steam engines working away in some factory; and as we forced our horses up the steep acclivity, over ground that resounded beneath their tread hollow and cavernous, we heard other sounds emanating from the deep bosom of the mountain.

He describes a number of springs, speaking of their cones and mounds, the lining of which resembled porcelain, and says:

There was a low rumbling sound accompanying the action of the first. The second worked exactly like a steam-pump, with a steady, regular stroke, the water being thrown out, not in a continuous stream, but in jets corresponding with the regular strokes of a piston. As we stood over it we could hardly divest ourselves of the impression that we were standing above a well-regulated steam engine in full operation, as, in fact, we were. We timed the pulsations with our watches, and counted just one hundred in a minute. From many small orifices, some not larger round than one's finger, all around us the steam was escaping; and the whole *mesa* seemed a mere crust perforated like a cullender. * * *

Looking southward along the height extending over half a mile of space, we saw dozens of these hot-water volcanoes, if we may be permitted the expression, in full operation, and an immense number of others quiet for the moment, but bearing evidence of being in working order. The largest of those quiet for the moment had an orifice as large as a sugar hogshead, and was filled to the surface with clear, sparkling water.

The water in the basin, though not boiling, was not quite cold enough for bathing

* Overland Monthly, February, 1869.

purposes, and we concluded to wander on a little further and wait for it to cool. * * * While we were sitting with our feet in the tepid water discussing the formation of the place, a low, droning, moaning sound came up from the deep bosom of the hill, followed by a sharp clap! clap! clap! as if a pair of giant hands had been struck together three times with force; then with a tremendous swash a torrent of scalding water flew into the air, scattering in all directions from the great spring in which we had just been proposing to bathe, and poured in a stream 10 feet wide down the hill.

MUD VOLCANOES OF SOUTHERN CALIFORNIA.

In Appleton's American Encyclopedia, Mr. John D. Champlin, in his article on geysers, describes a locality in the Colorado Desert between latitude 33° and 34°, and longitude 115° and 116°, which contains remarkable mud volcanoes and boiling springs. This is probably the same locality indicated on the United States Engineers' map, about 65 miles northwest of Fort Yuma and 50 miles north of east from San Felipe, near the railroad station Volcano, and it is without doubt the same locality that is described in the proceedings of the California Academy of Sciences for 1857, by J. A. Veatch, as being 60 miles northeast of San Felipe.*

Mr. Champlin, in a letter to the writer, says he has mislaid the notes from which he wrote his article, and does not recall the source of his information, but is of the opinion that he obtained the facts from some official report. His description is as follows:

> The desert at this point is below the level of the sea. The springs cover a space not more than a quarter of a mile square. This area is covered with soft mud, through which water and steam are constantly escaping with a noise audible at a distance of 10 miles. In some places the vapor rises steadily with a sharp hissing sound, in others it bursts forth with a loud explosion, throwing water and mud to the height of 100 feet. Some of the boiling springs throw up a column of water 20 or 30 feet; some have cones formed around them, and some have basins 100 feet in dameter in which the blue, paste-like mud is ever bubbling and hissing. Many are incrusted with carbonate of lime, others with deposits of sulphur. The steam which rises from them is strongly impregnated with sulphur.†

Dr. J. Le Conte also describes these springs in Silliman's Journal,‡ and was told of a similar locality southeast of Fort Yuma. The railroad now passes near these Springs.§

GRANITE CREEK BOILING OR MUD SPRINGS.

In Northwestern Nevada at the south end of Granite Range, on the border of Mud Lake, about 3 miles southwest of Granite Creek Station, is an interesting group of hot springs, described as follows by Hague and Emmons.

> Scattered over an area roughly estimated at 75 acres are a large number of pools, mostly circular, varying in size from 1 up to 25 feet in diameter, and surrounded by a luxuriant growth of brilliant green, alkaline grasses, in marked contrast to the dull monotonous colors of the desert. The waters are clear and quite palatable when cool. The largest one visited had a temperature of 194° in the broad open pool; others indicated temperatures from 188° up to the boiling point, and yielded large volumes of

*(Proc. Cal. Acad. Nat. Sciences, 1857, p. 104.) Veatch says there are from three to fifteen mud cones in a space of 500 by 350 yards. Some are sharp cones, others are dome-shaped. Steam rushes constantly from many, and is intermittent in some. One throws a stream of water from 15 to 30 feet into the air. The illustration accompanying his article shows them to be remarkable. Some of the blue-mud caldrons are 100 feet in diameter, and are 5 to 6 feet below the surface.

†Appleton's Encyclopedia, Vol. VII, p. 785.

‡January, second series, 1855, No. 55, Vol. XIX, p. 1.

§W. H. Russell in his Notes from the West, published in London, in 1882, mentions visiting these springs, which he says are not far from the line of the railroad.

vapor that could be seen many miles across the desert. Along with these springs are a number of mud springs, or, as they are called, "mud volcanoes," round basins, from 2 to 3 feet below the surface of the ground, and varying from 6 inches to 6 feet in diameter. These were filled with mud and slime, the contents being thrown up and violently agitated at regular intervals, accompanied by puffs of steam. Several of these springs had built up cones of hardened mud, and all, with one exception, closed at the top. In this one, the aperture was about 2 inches in width, and emitted a very perceptible odor of sulphuretted hydrogen; it is said occasionally to throw out mud and water in all directions for a distance of 100 yards. Fragments of this ejected material were found by analysis to have the composition of clay.*

From what we have just written it will be seen that we have a number of Hot Spring localities that are of considerable importance and would attract considerable notice were they not dwarfed by comparison with the more extensive thermal development in the Yellowstone National Park.

The springs of Nevada and California are usually found in connection with volcanic rocks which are of Tertiary age. The following catalogue presents only the localities without giving the number of springs. With more careful exploration of the West this list can probably be greatly enlarged.

Table of thermal springs of the United States.

[For authorities in which springs enumerated in this table are referred to, the reader is referred to Bibliographical Appendix D.]

Locality.	State or Territory.	Highest temperature.
		°F.
Lebanon Springs	New York	73
Eleven miles from Carlisle, at Mount Pisgah	Pennsylvania	72
Sweet Springs, Alleghany County	Virginia	78
Buford's Gap Springs, Bedford County	do	75
Warm Spring's, Bath County	do	97½
Hot Springs, Bath County	do	108
Healing Springs, Bath County	do	88
Sweet Alum Spring, Bath County	do	85
New Milford, Page County	do	66
Streckler's Springs, Rockbridge County	do	70
Holston Springs, Scott County	do	68½
McHenry's Springs, Scott County	do	68
Snake Run Springs, Sweet Springs Valley	do	72
Berkeley Springs Bath, Morgan County	West Virginia	74
Sweet Springs, Monroe County	do	74
Red Sweet Springs, Monroe County	do	78
Warm Springs, Madison County	North Carolina	102
Warm Springs, Buncombe County	do	104
Warm Springs (36 miles from Columbus)	Georgia	90
Warm Springs (on French Broad River)	Tennessee	95
Florida Sulphur Springs	Florida	70
Washitaw Hot Springs, Hot Spring County	Arkansas	150
On the Rio Grande below Fort Quitman	Texas	
Yellowstone National Park	Wyoming	Boiling.*
Hot Sulphur Spring near Sheep Mountain	do	96
Hot Sulphur Springs near Camp Brown	do	110
Big Horn River	do	
Warm Springs, Wind River, northeast of Union Pass	do	
Near Laramie	do	71
Snake River below mouth of Hoback's River	do	117
Ten miles west of Fort Laramie	do	74
Sulphur Springs 12 miles north of Del Norte, near Wagon Wheel Gap on Rio Grande.	Colorado	150
Arkansas River, 3 miles below the mouth of the South Arkansas.	do	
Ouray at head of Uncompahgre River	do	Warm.
Poncho Creek, 1½ miles above Junction with South Arkansas.	do	
Cañon City	do	100
White Earth River	do	84
Four miles east of Cañon City	do	
Twelve miles northeast of Pagosa	do	78
Three miles southeast of Pagosa	do	120

* For complete lists of Yellowstone National Park, the reader is referred to Part I of the report.

* United States Geological Survey of the Fortieth Parallel, Vol. II. Descriptive Geology, page 799.

FIG. 16.—Steamboat Spring on Bear River, near Soda Springs, in Idaho Territory.

Table of thermal springs of the United States.

Locality.	State or Territory.	Highest temperature.
		°F.
Idaho Springs	Colorado	115
Grand River above Grand Cañon	do	112
Parnassus Springs on Red Creek 12 miles southwest of Pueblo.	do	72½
Mound Soda Spring, Park County	do	70
Sulphur Springs, Hertzel's Ranche, Park County	do	
Sulphur Springs, Middle Park	do	116
Sulphur Springs, South Fork Navajo River	do	80
Mound Sulphur Spring, South Park	do	107
Chalk Creek, Lake County	do	112
Near Conejos	do	
Ojo de los Caballos, San Luis Park	do	111
Pagosa Springs	do	138
Animas Valley	do	
On Rio Grande, north of Santa Barbara	New Mexico	
North of Mount Pelabo	do	
Near Miembres, 16 miles southeast of Camp Bayard	do	130
Apache Tahoe, 7 miles south of Camp Bayard	do	97
Hot Springs on Indian reservation west of Fort Craig	do	
Ojos Calientes, 2 miles northeast of Jemez	do	169
Cañada Alamosa, Socorro County	do	84
At copper mines of the San Francisco River	do	130
Ojo Caliente, 50 miles north of Santa Fé	do	150
Five miles west of Las Vegas	do	140
Diamond Creek, near its mouth, Socorro County	do	151
Ten miles south of Zuni	do	
Gila River near Diamond Creek	do	100
On Rio Pajarito	do	68
Lava Springs, Grand Cañon of Colorado	Arizona	89
Pahghun Spring	do	100
Prieto River	do	
Burke's Station, Gila River	do	
Near Tubac	do	
Head of Jordan Valley	Utah	128
Juab Valley	do	
Twelve miles north of Brigham City	do	132
Ten miles north of Ogden	do	136
Mouth of Ogden Cañon	do	150
One mile north of Salt Lake City	do	
Two miles north of Salt Lake City	do	128
Spanish Fork Cañon, Wahsatch Mountains	do	145
North end of Utah Lake	do	Warm.
Sixteen miles west of Minersville	do	185
Fish Springs	do	74
Cave Spring Settlement, west base Mineral Range, North end of Onaquin Mountains.	do	74
Head of Provo Cañon	do	72
Near Medway	do	110
Undine Springs, Labyrinth Cañon of the Colorado	do	
"Narrow Cañon" of the Colorado	do	91
Snake River, 3 miles below Salt River	Idaho	144
Snake River below Lower Cañon	do	
Lincoln Valley near Fort Hall	do	87
Steamboat Spring, Bear River bend	do	87¾
Near Fishing Falls, north of Snake River	do	164
Lou-lou fork of Bitter Root River	Montana	132
Twenty-five miles east of Flathead Lake	do	
Hunter's Hot Springs, Yellowstone River	do	120
Shields River	do	
Helena Hot Springs	do	
Big Hole Prairie	do	132
Deer Lodge Prairie	do	
Hot Spring district, near Red Bluff	do	124
Deschutes Valley, on Wamchuck River	Oregon	145
North shore of Goose Lake	do	
Malheur River	do	164
West side of Blue Mountains	do	
Butte Creek, near Harney Lake	do	
Upper end of Degroot's Valley, Lander County	Nevada	
In south end of Smoky Valley	do	
Near Kepler's Station, 40 miles east of Walker's Lake	do	
South of Wadsworth	do	73
Sou Hot Springs, Osobb Valley	do	185
Seven miles south of Sou Springs, Osobb Valley	do	125
Silver Peak, Esmeralda County	do	117.8
Diamond Valley, 30 miles north of Eureka	do	150
San Antonio, Nye County	do	
In Big Smoky Valley, south of Toyabe, Nye County	do	
Ten miles south of Ophir Cañon, Nye County	do	
Hot Sulphur Springs, Carline	do	
Hot Springs, Reese River Valley	do	130

Table of thermal springs of the United States—Continued.

Locality.	State or Territory.	Highest temperature.
Warm Spring Creek, Independence Valley	Nevada	
Hyko, Lincoln County	do	90
Hot Creek mining district, Nye County	do	
Five miles east of Patterson, Nye County	do	
Volcano Springs, Lander County, southeast of Beowawe	do	Boiling.
Grass Valley 3 miles south of Bardmass Pass	do	181
West of Fish Creek Mountains	do	
Rock Creek Valley	do	
Antelope Valley, near Eagle Lake	do	
East base of Kern Mountains	Eastern Nevada	
East base of Humboldt Mountains	Nevada	170
Near Pyramid Lake	do	208
On pyramid in Pyramid Lake	do	Warm.
Las Vegas	Southern Nevada	73
Boiling Spring north end of Mud Lake	Nevada	
Ash Meadows	Southern Nevada	81.6
Rabbit Hole Springs	Nevada	60
Hot Spring west of south end of Black Rock Mountains	do	
Double Hot Springs, west flank of Black Rock Mountains	do	171
Steamboat Springs, Virginia Range	do	204 Boiling.
Hot Spring, Elko County	do	
Hot Spring, Elko	do	192
Hot Spring 30 miles south of Argenta, Lander County	do	
Hot Spring 30 miles east of Walker's Lake, Esmeralda County.	do	
North bend of Walker's River	do	165
Thirty miles east of Austin	do	
Steptoe Valley, White Pine County	do	
White Pine Valley, White Pine County	do	
Puebla Hot Spring, Humboldt County	do	
Thousand Springs Valley	do	Boiling.
Antelope Valley	do	
Ruby Valley near Ruby Lake	do	
Little Cedar Mountains	do	
Warm Sulphur Spring, Spring Valley	Eastern Nevada	
Hot Spring, north of Winnemucca, Humboldt County	Nevada	
Near Hot Spring Station, on Central Pacific Railroad, east of Winnemucca.	do	189
Hot Spring, 20 miles southeast of Winnemucca	do	
Hot Spring Butte, north end of Truckee Range	do	Boiling.
Emigrant Cañon, Tucubit's Range	do	
Lake Tahoe, Hot Springs	California	
Calistoga Springs	do	195
Napa Valley	do	169
Geyser's, Sonoma County	do	207
Mud Volcanoes, 60 miles northeast of San Felipe, San Diego County.	do	
Summit of Shasta Peak	do	
Agua Caliente, near Warner's Ranch, San Diego County	do	142
Border of Colorado Desert	do	120
San Bernardino	do	172
Near Walker's Pass	do	
Hot Sulphur Springs, Santa Barbara	do	130
Kern County	do	
Paso Robles, Hot Springs	do	122
Bridgeport, Mono County	do	
Geyser and Hot Springs, 25 miles south of Mono Lake, Inyo County.	do	
South of Fort Bidwell	do	
Tuscan Springs, Shasta County	do	76
Skaggs' Hot Springs, Sonoma County	do	140
Near Honey Lake	do	
Deep Spring Valley, Inyo Valley	do	74
Benton, Inyo County	do	170
Near Mission of San Miguel, Obispo County	do	
Gilroy Hot Springs	do	
Guayamos Valley, Obispo County	do	
Near Fort Crook	do	
Saratoga Springs, south end of Death Valley	do	70
On island in Mono Lake	do	Boiling.
Ten miles east of Telescope Peak	do	80.7
Thirty miles south of Lake Tahoe	do	
Near Mohave River	do	
Clear Lake	do	
South of Bear Valley, near Clear Lake	do	200
Burton's Springs, north end of Owen's Valley	do	160+
Near Little Owen's Lake	do	Hot.
Twenty-five to 30 miles southeast of Owen's Lake, and 15 miles east of Little Lake.	do	Hot.
Geyser's, or Warm Sulphur Springs, 20 miles from Sitka	do	104
Island of Arkhun	do	Boiling.

Table of thermal springs of the United States—Continued.

Locality.	State or Territory.	Highest temperature.
Island of Unimak	Alaska	Boiling.
Island of Atka	do	do
Island of Adakh	do	do
Island of Sitignak	do	do
Island of Kanaga	do	do
Near the Youkon River	do	33*

*This spring never freezes, and when this temperature was obtained the air was at 10° F., so that it is properly a thermal spring.

CHAPTER IV.

THERMAL SPRINGS OF MEXICO, CENTRAL AMERICA, WEST INDIES, AND SOUTH AMERICA.

Our knowledge of the thermal springs of Mexico, Central America, the West Indies, and South America is comparatively meager, being limited mainly to the casual mention of various travelers, and the catalogue appended to this chapter is therefore deficient, especially in the record of temperatures. Very few travelers have the means of obtaining the temperatures accurately, and usually they simply state that the springs are warm, hot, nearly boiling, or boiling, their thermometers being in most cases their own bodies, which we know are not at all reliable for such purposes.

The volcanic band extending southward from North America through Mexico, Central America, and South America is second only to that extending from Kamtschatka, through Japan and Formosa, into the Eastern Archipelago, and in regions of such extensive volcanic action we naturally look for a considerable development of thermal springs, and that we do not look in vain is shown in our catalogue, incomplete as it undoubtedly is. With extended knowledge in the future, the list will be enlarged, and areas of veritable geysers, equal to any now known, may possibly be discovered.

MEXICO AND CENTRAL AMERICA.

An almost continuous line of volcanoes stretches through Mexico and Central America. Twenty-five active volcanoes, according to Judd, are known to exist in Central America. The distribution of thermal springs corresponds to that of the volcanoes.* One of the volcanoes of Guatemala, viz, the *Volcan de Agua* or Water Volcano, might be considered as a geyser on a grand scale, as it erupts water during its periods of activity.

At Aguas Calientes, near Los Banos, in the neighborhood of San Luis Potosi, Mexico, there is a geyser from which the water spouts to the height of 10 or 12 feet with a great escape of steam, the column of which can be seen at a great distance.†

On the slope of San Andres, an ancient volcano of Mexico, there is

*Volcanoes, by John W. Judd, New York, 1881, p. 227. Mexico is probably included, although not so stated.

†Summerland Sketches in Mexico, &c., by Felix Oswald, Phil., 1880.

a hot spring which deposits silica, which is soft at first (gelatinous silica), and afterwards becomes opaline. In the same region, also, near Jaripeo and Taximaroa, there are boiling springs and mud holes.* The mud volcanoes and springs of Central America are exactly similar to those of the western part of the United States, already described. Those at San Jazinto, in Nicaragua are said by Froebel to be at the boiling point, and of various colors, viz: red, brown, yellow, blue, black, and white.†

WEST INDIES.

There are six active volcanoes in the West Indies,‡ the great center of activity being in the western line of the Caribbee Islands (Windward Islands), which are the continuation, northward, of a branch of the volcanic line of South America. The thermal springs of Venezuela are on this line, and make a connecting link between those of Caribbee Islands and those of the main chain of the Andes.

The larger islands of the West Indies, lying more to the westward, are not igneous, but they are subject to earthquakes, especially Jamaica and St. Domingo. In the latter island the earthquake of 1770 caused hot springs to break out where no water previously existed, but they afterwards ceased to flow.

The temperatures of the springs in Jamaica and Cuba are comparatively low, and high temperatures are not noted until the Caribbees are reached. Almost every one of the Windward Islands has its *soufrière* or sulphur, connected with which are hot springs. St. Lucia and Dominica are especially noted for their hot springs. The *soufrière* of St. Vincent contains a lake, the color of which is described as being an opalescent green.

SOUFRIÈRE OF ST. LUCIA.

The *soufrière* or sulphur of St. Lucia is in the crater of a volcano, 1,000 feet above sea level, and occupies an area of about three acres, in which space there are at least fourteen caldrons in a state of constant ebullition, boiling to the height of 3 or 4 feet, the steam having a sulphurous odor. In some of the caldrons the water is clear, in others it is black. Fresh springs and fountains are continually breaking out. This place was once celebrated for medicinal purposes, and baths were constructed.§

BOILING LAKE IN THE GRAND SOUFRIÈRE OF DOMINICA.

The boiling lake of Dominica was known as far back as 1777. It is a seething caldron, measuring 200 by more than 100 yards, with perpendicular walls 60 to 100 feet in height. At a distance of 10 feet from the edge there is no bottom at a depth of 195 feet. It is 2,400 feet above sea-level, and is in active ebullition, especially in the center, where it is geyser-like, the water being thrown in jets into the air, shifting from side to side with a noise like the discharge of artillery. The temperature at the edge, according to Palgrave W. Gifford, is 185° F., and farther in is 200° F.,‖ and in the center is doubtless at or even above the boiling point, which here is about 207° F.

* Saussure's Excursion to an Ancient Volcano in Mexico, Jour. Geog. Soc. of London, Vol. XXX, 1860, pp. 53-58.

† Seven Years Travel in Central America, &c., by Julius Froebel, London, 1859.

‡ Judd, *ib. cit.*

§ St. Lucia, by Henry Breen, London, 1844, pp. 7, 8.

‖ West Indian Memories, by Palgrave W. Gifford, MacMillan's Mag., Vol. XXXV, No. 209, March, pp. 361–374.

Dr. Nichols, who discovered the lake, gave a temperature of 196° F.; Mr. Prestoe, of Trinidad, 180° to 190°, and both found it boiling; while Mr. F. A. Ober found it quiet, with a temperature of only 96° F.* It therefore appears that this is a true geyser, having periods of quiet. Its eruptions must be on a grand scale, those already mentioned being probably only the frequent explosions noted as so common in most geysers during the intervals separating the true eruptions.

THE PETITE SOUFRIÈRE OF DOMINICA.

The Little Sulphur of Dominica is passed *en route* to the Boiling Lake of the Grande Soufrière. It is about 2,000 feet above sea level, and its largest spring is 5 feet in diameter, with a temperature of 208° F. The locality is described as follows by Mr. F. A. Ober:†

> The basin was covered with rocks and earth, white and yellow, perforated like the bottom of a colander, whence issued steam and vapor and sulphur fumes, hot air, and fetid gases. There was a full head of steam on, puffing through these vents with the noise of a dozen engines. There were spouting springs of hot water; some were boiling over the surface, some sending up a hot spray, some puffing like high-pressure steamboats. Clouds of steam drifted across this small valley, now obscuring every rock and hole, now lifting a few feet only to settle again. * * * Several streams ran down and out, uniting in a common torrent; streams hot, impregnated with sulphur, streams cold, clear, and sparkling, only a yard apart; water of all colors, from blue and green to yellow and milk-white.

SOUTH AMERICA.

The entire western coast of South America is igneous, the Andes continuing southward the volcanic line of Mexico and Central America. There are said to be thirty-seven active volcanoes known in South America, and the gaps between are filled with cones that are now supposed to be extinct, but which may become active in the future.

In Peru and Ecuador terrific earthquakes and eruptions of mud and water in torrents have been frequent. We find that thermal springs are found from one end of the Andean chain to the other. Even Patagonia has its hot springs. In Bolivia they are said to be innumerable. In the Argentine Republic the springs are found either in the Andes or near there, in the western part of the territory. The springs of Chili and Ecuador are numerous, those of Chili being saline, sulphurous, and calcareous, ranging in temperature from 50° F. to the boiling point. The springs of Chili are almost all found at the foot of the Andes, or on its slopes. The most noted locality is Chillan, although all have been used for medicinal purposes more or less, and have facilities for baths. As already noted, a line of volcanic action running through Venezuela connects the Andes with the Caribbean line. The thermal springs of Venezuela follow this line from the east to the west, the most noted localities being Las Trincheras (described by Humboldt and long known), Onoto Mariara, and that of the Quiva or Cuiva, near Coro. The last is the most remarkable, containing about 40 caldrons, in which water of all colors can be found, the temperatures ranging from 40° F. to 150° F.

Brazil has no known volcanoes, and her thermal springs are found in the eastern part of the empire, in connection with the coast mountain ranges, not over 100 to 200 miles from the coast. They would therefore seem to hold the same relation to the hot and boiling springs found in

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* Camps in the Caribbees, by Fred. A. Ober, Boston, 1880.
† *Ibid.*, page 60.

the Andes that the thermal springs of the Appalachian region of the United States do to the geysers of the Yellowstone and the hot springs of Nevada and California. The analogy can be carried still further, as the table-lands of the Amazon, like the Mississippi Valley, are destitute of thermal springs. In the Argentine Republic the springs are found near the Andes in the west. Mendoza, which is the center of the region, is frequently subject to earthquakes, and in 1861 12,000 out of 15,000 people were destroyed there by an earthquake.

BATHS OF CHILLAN, IN CHILI.

The most noted springs in Chili are those of Chillan, on the Nevada Chillan, near the volcano of Antuco. They are near the region of perpetual snow, and accessible only in summer. The highest temperature recorded by Lieutenant Gillis, from whose description these notes are taken,* is 190° F. The springs, according to him, are mostly sulphureted, the escape of sulphureted hydrogen being very great, and the water, after standing, depositing sulphur, although very clear at first. A great many of the springs are in constant ebullition, and the rocks are so hot that the stream in passing over them is converted into steam with a hissing noise, while under foot is a roar as from gigantic steam-boilers. A cold spring is found in the midst of the hot ones.

In the following catalogue there is considerable discrepancy as to completeness in the various countries, but as far as the writer is aware it is the only attempt yet made to bring together in one list the springs of the regions indicated. There may be some duplications, but as far as possible they have been eliminated. The list for Bolivia is especially deficient, but all have been included of which records could be obtained.

Table of thermal springs of Mexico, Central America, West Indies, and South America.

[For the list of authorities for spring localities, &c., see Bibliographical Appendix E.]

Locality.	Country.	Highest temperature.
		°F.
Ojo Caliente, near Carrizal	Mexico	
Ojo Caliente, northeast of Saltillo	do	
Agua Caliente, east side of the sierra del Balcalele	do	
Aguas Calientes, about 80 miles west of San Luis Potosi	do	86
Chichimequillo, near Guanaxuato	do	206
Agua Caliente, between Tepuopes and Piedras Verdes	do	
Near Aguas Buenas, at the foot of Mount Cubilete	do	106
Near volcano of Jorulla	do	
On volcano of San Andres	do	Hot.
Mud volcanoes and springs near Jaripeo	do	Boiling.
Near Istapan	do	80
Near Lake Jalisco	do	
Penon de los Baños, Tescuco Lake	do	Hot.
Atliaca, 7 miles below Mirador	do	80
Amatlan	do	Hot.
On Pacific plains, between Chivela and Tarifa Passes, Tehuantepec.	do	94
La Chivela Pass, Tehuantepec	do	98
South and west slopes of Cerro Prieto, Tehuantepec	do	
Lake Amatitlan, Guatemala	Central America	Hot.
San Andres, Guatemala	do	
San Bartolome aguas calientes, Guatemala	do	Tepid.
On river Siguile, near Sunil, Guatemala	do	
Agua Caliente, Honduras	do	
Warm Springs of Almolonga, San Salvador	do	Warm.
Aguas Calientes, San Salvador	do	
In Ahuacapan, San Salvador	do	Hot.
Near Volcano of San Vincente, San Salvador	do	Hot.

* United States Astronomical Expedition to South America, 1840–'52, by Lieut. J. M. Gillis. Vol. II.

Table of thermal springs of Mexico, Central America, &c.—Continued.

Locality.	Country.	Highest temperature.
Boiling Lake (Aguachapa) San Salvador	Central America	Boiling.
Near Salama, San Salvador	do	Warm.
Near Volcano Vicjo, Nicaragua	do	Boiling.
In Lake Managua, Nicaragua	do	Hot.
Near Tepitapa, Nicaragua	do	Almost boils.
Base of Volcano Monotonebo, Nicaragua	do	Hot.
Mud Volcanoes at San Jazinto, near Leon, Nicaragua	do	Boiling.
Mud Volcanoes at Tisate, Nicaragua	do	
Agua de Salud, near Calobre	Panama or Darien	Hot.
Caldera, in Chiriqui	do	Hot.
Cape Corientes	do	Hot.
Mud Volcanoes	do	83
Banos de San Diego, on Caiguanobo River, Cuba	West Indies	95
Banos de Santa Fé, Cuba	do	80
Madruga, Cuba	do	
Guanabacao, Cuba	do	
Isle of Pines, near Cuba	do	
Sulphur River Valley, Jamaica	do	
Bath St. Thomas-in-the-East, Jamaica	do	
Milk River bath, in Vere, Jamaica	do	
White River, Jamaica	do	
Near source of Cabarita, in Hanover, Jamaica	do	
Caribbee Islands:		
On St. Christopher	do	
On isle of Nevis	do	
Soufrière of island of Montserrat	do	
Soufrière of Guadeloupe Island	do	
On the beach of Guadeloupe Island	do	
Boiling lake or geyser in Grande Soufrière, Dominica	do	200
Petite Soufriére of Dominica	do	*208
Near St. Pierre, Martinique	do	
Near Fort de France, Martinique	do	
Eaux Bouilli, Martinique	do	131
Island of St. Lucia	do	203
Soufrière on St. Vincent's	do	
Annandale, island of Grenada	do	86
St. Andrew's Parish, Grenada	do	Hot.
St. Mark's Parish, Grenada	do	
St. John's Parish, Grenada	do	
Mud Volcanoes 40 miles south of the Pitch Lake, Trinidad.	do	Boiling.
Carapano	Venezuela	
New Barcelona	do	Hot.
Aquas Calientes of Bergentine	do	109
San Juan	do	88
Las Trincheras, near Valencia and Puerto Cabello	do	206
Mariara or Mariana (?)	do	149
Onoto	do	112
Tachera	do	
Gulf of Cariaco	do	
Near Coro, on Cuiva River	do	152
Puoto	do	112
Paramo de Ruiz	New Granada or Colombia	157
Near Caqueza	do	Hot.
On plain of Bogota	do	Hot.
Tabio, 2 miles north of Bogota	do	114
Suba, 10 to 15 miles south of Bogota	do	Hot.
Agua Caliente, near base of Tolima Volcano	do	Hot.
On Coella River, near Toche	do	91
Belermos	Ecuador	
San Pedro del Tingo, northeast of Quito	do	
Cachillacta, in the district of Nanegal	do	
Rununagui	do	
Timbugpoya, near Tacunga	do	
On the slopes of Chimborazo	do	
Banos, near foot of Tunguragua	do	
Cuenca	do	162
Huanvelica, or Guanvelica	Peru	
Aguas Calientes, valley of Inisco	do	90
Catari, near Arequipa	do	
In province of Charcos	do	Hot.
Tingo Grande	do	
Tingo Chico	do	
Baths of the Inca, on Isle of Wolves	do	Hot.
Yauli	do	192
Baths of Yura	do	
Laguna de Tarapaya	Bolivia	93
Caiza, in district of Perco	do	
Urimeri, near Lake Aullagas	do	

*Boiling point here is about 208°.4 F.; in the Grande Soufrière it is about 207° F.

Table of thermal springs of Mexico, Central America, &c.—Continued.

Locality.	Country.	Highest temperature.
Machacamarca, near Lake Aullagas	Bolivia	
Chillan, on west flank of Cerro Nevada	Chili	*190
Baths of Toro, near Elqui	do	
Panimavida, near Linares	do	88.4
Apoquindo, near Santiago	do	74½
Colina, near Santiago	do	89½
Cauquenes, near Raucagua	do	120½
Tinguirrica, near Colchagua	do	
Mondaca, near Talca	do	111½
Trapa Trapa, near Los Angeles	do	
Nahuelhuapi, in Llanquihue	do	
Cato, south of Panimavila	do	96.8
Doña Ana, east of Serena, 10,000 feet above sea-level	do	140
Soco	do	
Near Borbollon	Argentine Republic, or La Plata.	77
Valley of Gualfin, in Catamarca	do	
Capaia, 100 miles south of Mendoza	do	
Boca del Rio, 50 miles south of Mendoza	do	113
Lagunta, 5 miles east of Mendoza	do	
Challao, 7 miles northwest of Mendoza	do	
Arroya de-Leyes, 25 miles east of Mendoza	do	
Papagallos, 6 miles west of Mendoza	do	
Villavicencio, in Uspallata Pass, 70 miles from Mendoza	do	
Puente del Inca, in Uspallata Pass, near the Chili border	do	97
Lulunta, near Lujan	do	
San Juan	do	89½
Los Reyes	do	65.7
Five miles east of Rosario de la Frontera	do	144–163.4
Between Geylum and Patagones	Patagonia	
Caldas, or Thermae de San José, or Agoa Santa	Brazil	72
Caxambu, in Baependy	do	
Itapicuru, in Bahia	do	106
Caldas, in Minas Ceras	do	113
Itabira	do	
Aguas Virtuosas of Campanha	do	
In district of Santa Cruz	do	119
In Santa Catharina	do	113

*Springs here are boiling.

CHAPTER V.

THERMAL SPRINGS OF EUROPE, THE AZORES, AFRICA, AND THE INDIAN OCEAN.

In Europe, outside of those areas contiguous to the Mediterranean, the thermal springs are located either in regions of faulting and dislocation, along the flanks of mountain ranges, or in regions of extinct volcanoes, as in Central France, Hungary, and parts of Germany.

In Central France there are hundreds of volcanic cones, especially in Auvergne, where the rocks are both basaltic and trachytic; and in this region we find one of the hottest of European springs, viz, that of Chaudes Aigues, with a temperature of 190°.4 F.

In Germany the springs of Eifel and Bertrich are near extinct volcanoes; and Hungary, where there are five distinct groups of volcanic rocks, is well represented in the list of European thermal springs included in this chapter.

The greater number of the springs are, however, found in connection with lines of dislocation, and at the foot or in the midst of elevated mountain ranges. On the north slope of the Pyrenees the springs correspond in direction with the trend of the chain; and all along the

southern slopes of the Alps, from Mont Blanc to the Euganean Hills, there is a continuous line of springs. Aix is at the intersection of three important axes of disturbance.

In European Turkey the springs are in north and south lines.

In England the thermal springs, which are few in number and low in temperature, are found in connection with limestones; and Mr. C. E. Batten, who has discussed the cause of the heat in the waters of Bath, concludes that it is due to their coming from a depth of over 3,000 feet.*

The steppes of Russia are without thermal springs until the Ural Mountains or the Caucasus are approached, being in this respect analogous to our Mississippi Basin, the table lands of South America, and the Siberian plains, which are without even warm springs as far as we know at present.

The temperatures of the springs in the regions just enumerated appear to have undergone but little change since the times of the Romans, especially at Aix, Mont Dor, Plombières, and Bath, all of which were known and used in the days of the Roman Empire, and probably long before by the barbarians whom the Romans conquered.

The only active volcano of the European continent is that of Vesuvius, and it is naturally grouped with Stromboli, Vulcano, and Etna, all being in the Mediterranean region. In Italy, the eastern or Adriatic side of the Apennines is destitute alike of hot springs and the evidences of vulcanism, the springs being found on the west side, where, as we have just noted, we have one of the most active and best known centers of volcanic activity.

Going eastward, we again reach an area of igneous rocks in the Grecian Archipelago, where the volcanoes of Santorin and Nisyros are active. The catalogue shows that here, also, is an area of thermal springs, some of them among the most noted in ancient times.

The deposits from the thermal waters of Europe are mainly calcareous, and have been immense in quantity, especially when the springs were more active. The calcareous tufas in Italy are of such thickness and hardness as to afford durable building stone, and they have been so utilized, especially in Rome. In Hungary, also, travertine has been used in the construction of all the houses in the town of Czelea. Enormous quantities of siliceous sinter and calcareous tufa are found in the district of Schemnitz in Hungary. At Compissade, a spring near Mont Dor, in France, the deposit is siliceous; and in Ischia and parts of Italy there are springs which deposit siliceous sinter, and the deposit from Ischia, to which the name of *Fiorite* has been given, corresponds in its chemical composition with the deposits from Iceland, New Zealand, and the Yellowstone National Park.

The thermal springs of Europe are so well known and have been so thoroughly studied that it is unnecessary to describe any of them here. For descriptions the reader is referred to the numerous publications relating to them, of which a partial list is given in the Bibliographical Appendix F.

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*See Proc. Somerset Archeol. Nat. Hist. Soc., Vol. XXII, pp. 52–60.

Table of European thermal springs.

[For authorities see Bibliographical Appendix F.]

Name or locality.	Country.	Highest temperature.
		° *F.*
Bath	England	120
Buxton	do	82
Clifton	do	76
Bristol	do	74
Bakewell	do	62
Matlock	do	66
Stony Middleton	do	63
Taafe's Well	Wales	70
Mallow	Ireland	72
Chaudfontaine	Belgium	92
Aix le Bains	France	111
Mont Dore les Bains	do	113
Chaudes Aigues	do	190.4
Lamotte	do	184
Plombières	do	125
Compagne	do	80
Vichy	do	105.8
Luxeuil	do	126
Neris	do	145
Bourbon Lancy	do	140
La Bourbonle	do	130
St. Armand	do	82
Bourbonne l'Archambault	do	125
Chateau Neuf	do	101
Evaux	do	137
Saint Laurent	do	122
St. Nectaire	do	101
Bagnoles	do	113
Campagne	do	81
Sylvanes	do	108
Digne	do	115
Greoulx	do	101
St. Sauveur	do	93
Balaruc	do	126
Vals	do	96
Rennes	do	113
Nevis	do	148
St. Paul de Fenouilhades	do	81
St. Allyre	do	.....
Acqui	do	167
Clermont	do	.....
Royat, near Clermont	do	95
Arles	do	145
Preste	do	131
Molitz	do	100
Thuez	do	171
St. Thomas Canavilles	do	135
Reynez	do	83
Enn	do	122
Escaldas	do	107
St. Didier, near Mont Blanc	do	95
Dorres	do	104
St. Maurienne, near Mont Cenis	do	Warm.
Los	do	84
Ax in Arriège	do	168
Ussat	do	100
Lez	do	86
Barèges	do	120
Cauterets	do	130
Eaux Bonnes	do	92
Eaux Chaudes	do	82
Dax, near Bordeaux	do	142
Barbontan	co	104
Castera-vivant	do	85
St. Gervais	do	106
St. Martino	do	118
Aix in Provence	do	117
La Perrier	do	99
Montiers	do	97
Echaillon	do	89
Bagnères de Bigorre	do	115.7
Bagnères de Luchon	do	131
Bourbonne-les-Bains	do	149
La Trinchere, near Valencia	Spain	194½
Tiermas, near Jaen	do	91.5
Caldas de Reyos	do	102
Solares	do	81½
Cuntis	do	102

Table of European therman springs—Continued.

Name or locality.	Country.	Highest temperature.
		° F.
Puente Viesgo	Spain	95
Las Caldas	do	99½
Ledisma	do	104
Hermida Springs	do	123.2
Arnidello	do	107
Trillo	do	91.5
Lurganes	do	68
Baza	do	86
Almeria	do	107
Graena	do	89
Puente Nerrisa	do	79.2
Alhama	do	112.5
Archena	do	113
Alceda and Ontameda	do	83.7
Buzot	do	104
Caldas das Taipas, near Guimareus	Portugal	91
Caldeilas de Rendusa	do	89
Canaveres, near Guimareus	do	93.2
Guimareus	do	138
Monçao, near Ucano	do	109.4
Carlão, Villa-real	do	92.8
Chaves, near Braganza	do	141.8
Pombal d'Anicaes, near Torre de Moncervo	do	95
Rede de Corvaceira	do	98.6
Alcafache, near Viseu	do	98.6
Aregos, near Lanrego	do	142¾
Cauas de Lenhorim, near Viseu	do	98.6
Carvalhal, near Visen	do	120.2
Chaves	do	142
Santa Gemil or Lagiosa, near Viseu	do	120.2
San Pedro Dosul, near Viseu	do	153.5
Prunto Azemba, near Coimbra	do	89.6
Ranhados, near Pinhel	do	107.6
Rapoila de Coa, near Castelbranco	do	94.2
Uuhaes da Serra, near Guarda	do	87.8
Caldas da Rainhas, near Alemquer	do	93.2
Cascaes Torres Vedras	do	84.2
Gaieiras, near Alemquer	do	91.4
Lisbon	do	86
Miorga Alcobaça	do	82.4
Torres Vedras	do	111.2
Cabeço de Vide	do	80.6
Monchique, near Lagos	do	92.7
Pfeffers	Switzerland	99½
Leuk	do	123
Weissenburg	do	81½
Loueche	do	123
Schinznach	do	88½
Baden	do	127
Aix la Chapelle	Germany	131
Burtsheid or Borcette	do	171½
Bertrich	do	90
Eifel	do	121
Ems	do	115
Wiesbaden	do	155¾
Schlangenbad	do	89½
Nauheim	do	99.9
Baden Baden	do	155
Wildbad	do	98
Baden Weiler	do	81½
Krentznach	do	86
Wolkenstein	do	83½
Warmbrunn	do	97
Landeck	do	85½
Carlsbad	Bohemia	162½
Toplitz	do	122
Gastein	Austria	160
Montefalco, near Trieste	do	106½
Baden	do	119½
Uttersdorff	do	88½
Doppelbad, near Gratz	do	83¾
Römerbad, near Cilly	do	99
Neuhaus, near Cilly	do	97½
Töplitza	do	97½
Töplika	do	133¼
Krapina	do	113
Szulenczha	do	104
Lipiker	do	124¼
Ofen or Buda	Hungary	144½

Table of European thermal springs—Continued.

Name or locality.	Country.	Highest temperature.
		°F.
Trencsin	Hungary	104
Postheny, near Presburg	do	146¾
Stuben, near Kremnitz	do	110
Harkány	do	144.7
Ribar, near Neusohl	do	78
Altsohl, near Neusohl	do	83¾
Lucska	do	77
Budos, near Fünfkirchen	do	137¾
Vichnye (Eisenbach), near Schemnitz	do	101
Skleno (Glosshütte), near Schemnitz	do	120
Parad, near Erlau	do	86
Borsah	Transylvania	
Mehadia	do	137
Acquadella Bollente	Italy	167
Valdieri	do	146¾
Vinadia	do	153½
Craveggia	do	81½
Roccabigliera, near Nice	do	81½
Abano, near Padua	do	181
Lucca	Tuscany	124
Monte Cerboli	do	110
Pisa	do	106
Monte Catini	do	82
Bagni de San Filippo	Italy	110
Civita Vecchia	do	86
Sulphur Lake, near Tivoli	do	80
Puzzuoli	do	98
Baths of Nero	do	182
Pisciarelli	do	112
Torre de Annunziata	do	87
Gurgitello	Ischia	149
Aqua de Cappone	do	88
Olmetello	do	105
Citara	do	123
Bagni d'Ischia	do	113
La Restitua	do	123
Coquinas	Sardinia	159
Aqua Cotta	do	105
Benetutto	do	100
Sardara	do	112
Guitera	Corsica	122
Guagno	do	118
Termini	Sicily	110
Sciacca Baths of St. Calogero	do	126
Lutrake	Greece	
In the Morea, near Methone	do	
Thermopylæ	do	113
Neopatras, near Thermopylæ	do	Hot.
Korantzia, near Mount Geranicus	do	87.8
Near Egina	do	
Hot Baths of Venus, east of Corinth	do	
Six leagues from Patros	do	96.8
Methana at Vromo Lymni	do	98
Venetiko, west of Lepanto	do	
Dipso, or Edipsos, in Negropont, or ancient Eubœa	Grecian Archipelago	Boiling.
Milo (ancient Melos)	do	131
Thermia, or Cynthos	do	81½
Stalimene (ancient Lemnos)	do	
Touzla, on Mitylene (ancient Lesbos)	do	117
Kelemyehoulunzah, on Mitylene	do	102
In the pass above Eske Zaghra	Turkey in Europe	140
Lija, near Burgas	do	120
Langaga, nine miles from Salonica	do	
Therma (ancient Emathea), plains of Salonica	do	
Sarepta, on River Volga	Russia	
Seto Klintschy, in Perm	do	
Baths of Terek	Caucasia Russia	191½
St. Andrew's Bath, on Koyssa, near Kitzliar	do	Warm.
Tiflis	Trans-Caucasia or Georgia.	94½
Near Mount Maschuka, on the Podkumka	do	155
Kurtshan	do	Hot.
Near Ahkoor River	do	Boiling.

THERMAL SPRINGS OF THE AZORES, AFRICA, AND THE INDIAN OCEAN.

In the Atlantic Ocean, on a line which is approximately that of 20° west longitude, there is a line of volcanic islands, of which Iceland is

the northern one, with its thirteen volcanoes. Farther southward are the Azores, then the Canary Islands, south of which are the Cape Verde Islands. These all lie on the great submarine ridge which divides the Atlantic into two basins. On this ridge, according to Judd, there are forty active volcanoes, three of them being submarine. One of the latter broke out south of the Cape Verde Islands in 1824. The springs of Iceland have already been described in Chapter I. We have the Azores yet to mention.

With the African springs I have also included those of the islands of the Indian Ocean, Madagascar, the largest, being in such close proximity to the African continent as to be best considered here, and the islands of St. Paul and Amsterdam being small and unimportant.

THE CALDEIROS OR BOILING FOUNTAINS OF THE AZORES.

The Azore Islands, as we have just mentioned, mark one of the volcanic centers of the Atlantic Ocean Ridge, and we are not, therefore, surprised to find in them hot springs, such as are seen in the valley of Furnas, in the island of San Miguel or St. Michael's; this island has been the most disturbed by earthquakes. Hot springs are found in all parts of the island, but especially in two places at the west end, in the valley just mentioned, which is almost circular, about 12 miles in circumference, surrounded by volcanic mountains. Through it flows the Ribeira Quinte or Warm River. The springs, which are of high temperature and include some that spout to the height of 12 feet, are at one end of the valley, surrounded by deposits which are mainly siliceous sinters, white in color, streaked with reds, browns, and yellows. Sulphur covers the ground in some places, and there are blue mud springs. One group of springs is at the lake, which is 3 miles in circumference, and the other is close to the town of Furnas. The water is described as being bluish. At one place there are half a dozen jets in an acre of ground. The siliceous sinter from here was analyzed by Dr. Webster, and named Michaelite.*

A pumping sound is heard all the time from the boiling pools and steam holes. Wherever the water flows and evaporates, the siliceous sinter is deposited. It resembles that from Iceland, and surrounds the basins of the springs in rims 8 to 10 inches in height, as in the case of so many of the Iceland, New Zealand, and Yellowstone hot springs.

Dr. Webster gives the temperatures of fifteen springs, the lowest of which is 73° F., and the highest 207° F. Dr. Bullar gives the highest temperature as about 212° F., and the following list of the principal springs is made up from his description.† Thompson gives 194 as the highest temperature:

Name.	Temperature.	Remarks.
	° F.	
The Great Caldeira	212	The water is opaline, and gives off sulphureted hydrogen, boiling to the height of 3 or 4 feet. The basin is circular, 10 feet in diameter, and the deposits are siliceous.
The Quenturas	105	A carbonated chalybeate water.
Devil's Mouth	.....	A caldron of boiling blue mud.
Misturas	.....	
Agoa Azêda	.....	
Agoado férro	.....	

*Amer. Jour. Sci. and Arts, first series, Vol. III, p. 391.

†A winter in the Azores and a summer at the baths of the Furnas, by Jos. Bullar, M. D., and Henry Bullar.

AFRICAN THERMAL SPRINGS.

The African continent, so far as known, is of all the continents most free from volcanic action, and we do not, therefore, expect to find hot or warm springs at all prominent, except in connection with its mountains.* There are only ten volcanoes in Africa, and earthquake shocks appear to be comparatively unknown. This dark continent, however, is having light shed upon it, and its future geological exploration will doubtless reveal the presence of many thermal springs. Still they will probably never equal those of other portions of the world, although we shall expect them to occur in or near areas of volcanic rocks, or near mountain ranges where there are faults and dislocations.

SPRINGS OF HAMMAM MESKHOUTINE.

These springs are in the province of Constantine, in Algeria, having a temperature of 203° F., and are remarkable for their deposit, which is calcareous. Most of it is white striped with bright colors. Some of it is in masses, like walls, one of which is 66 feet high, 4,921 feet long, and from 33 to 49 feet wide. In other places there are numerous crater-like cones.

The thermal springs of the northern part of Africa may be considered as on the volcanic line of the Mediterranean, referred to in the previous chapter. The Azores also lie on what may be considered the western extension of this line. Many of the springs given in the catalogue were celebrated in ancient times, and are marked now by ruins of baths erected in the past.

In Southern Africa the thermal springs are probably due in part at least to the presence of mountains. The different springs have considerable reputation for therapeutical use.

Madagascar has numerous thermal springs, but they are avoided by the natives, probably on account of superstitious fears for which reason Indians avoid the Yellowstone National Park. The two islands, St. Paul and Amsterdam, are volcanic craters. The former is generally described as having hot springs, although some mention only the latter. On St. Paul the springs are on the north side of the basin. One is called the Bath and the other the Drinking Fountain. The water is boiling hot except at high water, when the sea pours into the crater and lowers the temperature.

Table of the thermal springs of the Azores, Africa, and the islands of the Indian Ocean.

[For authorities see Bibliographical Appendix G.]

Locality.	Country.	Highest temperature.
		°F.
Furnas Valley, island of San Miguel	Azores	212
Near Santa Cruz, island of Flores	do	Hot.
Ghasa, in Morocco	Africa	95?
Toser, in Morocco	do	
Dra el Hammah, in Morocco	do	
Oran, in Algeria	do	
Hammam Rira, in Algeria	do	167
Hammam el Enf, in Algeria	do	Hot.
Hamman Verda, in Algeria	do	Hot.

* There are four volcanoes on the west coast and six on the east. The Camaroon Mountains, on the coast of Guinea, are volcanic. Artali, between the Red Sea and the Abyssinian plateau, is a volcano. Hot springs are prevalent in Abyssinia along the coast in connection with the volcanic formations, and are also abundant in the Danakel country.

Table of the thermal springs of the Azores, Africa, &c.—Continued.

Locality.	Country.	Highest temperature.
		°F.
Hammam Meskhoutine, in Algeria	Africa	203
Hammam Berda (ancient Tibiltanae) in Algeria	do	86
Near ancient Carthage, in Tunis	do	
Near ancient Utica, in Tunis	do	
Ghadames, in Tripoli	do	120
Near Ailat, in Abyssinia	do	150
Goramba, in Abyssinia	do	Hot.
Atzfut, in Abyssinia	do	140
Tahow, in Abyssinia	do	Boiling.
Mtagata	Central Africa	129½
Busi, at foot of Mount Kugu*	do	Hot.
Kwaniwas	do	115
Brand Vley or Valley	South Africa	145
Craddock Ford, Fish River	do	
On Assagaai River	do	
White River, in Utrecht	do	
Elands Spruit, north of New Scotland	do	
Warmbad, near Nylstrom, Waterberg	do	
Otijikango, or Great Barmen	do	149
Little Barmen	do	143
Windhoek, on the Schwagoup	do	162
Ranomafana, Madagascar	Indian Ocean	140
Betafo, Madagascar	do	130
Island of Amsterdam?	do	212
Island of St. Paul	do	212

*This spring is said to bubble up twice a day.

CHAPTER VI.

THERMAL SPRINGS OF ASIA MINOR AND ASIA.

ASIA MINOR.

The association of hot springs and volcanic action in various parts of Asia Minor is a well-known fact, and the Catacecaumene, or Burnt District, near Smyrna, with its volcanic cones and springs, is often referred to by ancient writers. Syria and Palestine abound in volcanic rocks, and have been the theater of volcanic eruptions and earthquakes innumerable, and in the region of the Caspian Sea the volcanoes of Demavend and Elburz connect the Asiatic chain with that of Europe by way of Asia Minor. The thermal springs of Asia Minor are frequently referred to by ancient writers.

Philostratus says that the Greek soldiers wounded in the battle on the Caicus were healed by the waters of Agamemnon's spring, near Smyrna. The wife of Constantine, in 797, and still later the Sultan Soleiman, are said to have been restored to health by the thermal waters of *Broosa* or *Prusia* in Asia Minor. Yalova, also in Asia Minor, was formerly called Helenapolis after Constantine's mother, the Empress Helena, who was restored to health by its thermal springs.

Herod is said by Josephus to have sought relief from his terrible disease in the thermal springs of Callirrhoë.* These remarks might be almost indefinitely extended if the space allowed us to do so.

The thermal springs of Asia Minor are said by Le Coq to be in north and south lines. One of the most celebrated localities in Asia Minor is

*There is some doubt as to the exact situation of the springs to which this name was applied.

that six miles from Laodicea, at the site of the ancient city of Hierapolis. The general resemblance to the Mammoth Hot Springs of Gardiner's River, in the Yellowstone Park, which are also calcareous, will be apparent from the following description by Prof. J. Lawrence Smith:*

SPRINGS OF HIERAPOLIS.

The site is seen for many miles before it is reached, as it rises abruptly from the north side of an extensive plain, and the sides of the hill are covered with an incrustation of dazzling whiteness for upward of a mile in length, and from this it has received its present name, *Panbuk-Kelescy* (cotton castle). Its thermal waters have always been its principal object of note, as evinced by the extensive ruins of baths. In fact, the very hill upon which the city stands owes its formation to the deposition of carbonate of lime from these waters, and it now rises upward of a hundred feet above the plain, with a width of about six hundred feet. Immediately behind the city rises another set of hills of calcareous rock, from which flow the waters in question. * * * The amount of water is very great, and it is so highly charged with carbonate of lime as to incrust all bodies that it comes in contact with; and it takes place so rapidly that the concretion does not possess great solidity, and frequently has a granular form, resembling driven snow.

In some places, as the waters flow over the steeply-inclined sides of the hill, it forms a succession of terraces at regular distances, that require but little effort of the imagination to liken to an amphitheater with its marble seats. At other places it flows over the precipitous sides 64 or 70 feet high, and 100 or 200 feet wide, incrusting the precipice with a snow-white sheet, which might be likened to a consolidated cataract; and, what adds to the delusion, at the base the incrustations have accumulated an irregular mass not unlike foam. This petrified stream extends several hundred feet into the plain. It has formed walls and dikes, and incrusts the grass and vegetation that it flows over, and many of the tufts of grass, in perfect verdure, are thickly incrusted near the roots with this white carbonate of lime.

Strabo, speaking of these springs, says that the people of the city conducted the waters along the vineyards and gardens wherever they wanted a wall, and the channels became long fences, each a single stone, formed from the deposits left by the water.

In the deposits, as described above, we have the same arrangement in terraces that we have seen in the Mammoth Hot Springs of the National Park and the Tetarata of New Zealand, and in all three there is the general resemblance to a frozen cascade. A photograph of the Hierapolis deposits in "Anatolica"† (opposite page 99) shows that the resemblance to the Gardiner's River Springs is striking. Similar small basins are seen on the sides of the main mass, although the latter does not appear to be so extensive as the main terrace at Gardiner's River, in the Yellowstone Park.

ASIA.

There are said to be about twenty-four volcanoes in Asia, twelve of them being in Kamtschatka. The volcanic line extends through Central Asia mainly between Siberia and China, turning southward and eastward into Turkestan. The distribution of thermal springs corresponds with the extension of this volcanic line. Thermal springs are found in Kamtschatka, in Southern Siberia, and in Turkestan and Northern Persia, south of the Caspian Sea. In the latter region there is a region called the "Field of Fire," reminding us of our own "Fire Hole" in the Yellowstone Park. The plains of Siberia appear to be destitute of thermal springs. It is not until the mountainous parts are reached that they are found. Many springs that in other places would be cold ought to be considered as thermal springs in Siberia. Thus, at Slatoust, Aleski, and Tomsk there are springs that never freeze, although the

* In "Original Researches: The Thermal Waters of Asia Minor," page 98.
†Anatolica, by Rev. E. J. Davis, London, 1874.

temperature of the air be at—40° F., or even lower*. At Yakutsk the soil is said to be frozen to the depth of 630 feet.†

Farther south there is a volcanic line of mountains extending eastward from Turkestan into Asia—the Thian Shan Range—and in connection with this there are thermal springs.‡ Central Asia, and especially Northern and Western China, is a terra incognita, and every year adds something to our knowledge of its geological features. In 1871, Colonel Montgomery discovered in Great Thibet, near Lake Namcho, or Tengri Nur Lake, a geyser region of considerable interest, which in future examination may prove as interesting as those already known. This will be briefly described further on in this chapter.

The list of Indian springs in the accompanying table is taken mainly from the enumeration given in the journal of the Asiatic Society, Bengal, Vol XXXIII, by Robert de Schlagintweit, and is, therefore, in much greater detail than any other part of the table, a fact which must be borne in mind in the comparison of the different parts of Asia. India is not primarily an igneous region, although it is not destitute of volcanic rocks,§ and has been subject to earthquake shocks. Its thermal springs will be found mainly in connection with its mountain ranges in the peninsula, and especially in the Himalayas, where there is great disturbance in the position of the rocks. The list of Chinese springs is extremely limited, not because of any probable lack of springs in China, particularly in the west and north, but on account of the meager information we possess regarding the physical features of the Chinese Empire. The two localities in Eastern China—Yung-Mak, near Macao and Foo-chow-foo—are on the coast, and may have some connection with the hot springs of Formosa, which are opposite this part of the Chinese coast. In the northern part of the province of Chihli warm springs are common at the foot of the hills, and this is probably true also of most of the northern and mountainous portions of China. In the Malayan Peninsula the proximity of Sumatra will account for the springs of Ayer Panas.

THE HOT SPRINGS AND GEYSERS OF THIBET.

In the province of Chamnamring, called Chang, near the Lake Namcho or Tengri Nur, Col. I. G. Montgomerie, in 1871, discovered an interesting hot spring and geyser locality, which he describes in an article in the Journal of the Geographical Society of London. The following brief description of two of the areas is from his narrative.‖ On the 28th of December, 1871, he reached "Chutang Chaka, where there are some fifteen hot springs, whose water was found to be at a temperature of 166° F., boiling water at the same place only rising to 186° F. The water has a smell of sulphur." On the 30th they came to "Peting Chuja, near which place there is a large stony area from which a dozen columns of hot water issue and rise to a height of 40 or 50 feet, producing so much steam that the sky is darkened by it," and the noise was so great that the travelers could not hear one another speaking. The water of these jets was 176° F.

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*Travels in Siberia by Adolph Erman.

†The mean temperature of Yakutsk is about 12½° F., according to Milne. *Trans. Asiatic Soc. of Japan, Vol. VII, Part I.*

‡ See Semenof's first ascent of the Tian Shan, or celestial mountains. *Jour. Geog. Soc.* 1861, *pp.* 361, 362.

§ The Deecan trap (basalt), in the Indian Peninsula, covers 200,000 square miles, and is of Cretaceous and Tertiary age.

‖ Narrative of an exploration of the Namcho or Tengri Nur Lake in Great Thibet, &c., *Jour. Geog. Soc. of London, Vol. XLV, p.* 317.

Similar jets were noticed issuing from the middle of the adjacent river Lakú chu to a height of fifty feet. The "stony area" spoken of is probably a platform or mound of siliceous sinter, so common in geyser areas. He gives four other localities of hot springs in the same region, so that it must be quite extensive. The highest temperature recorded was 183° F. at Naisumchuja, where the boiling point of water is 183¾° F.

Table of thermal springs of Asia Minor and Asia.

[For authorities, see Biographical Appendix H.]

Locality.	Country.	Highest temperature.
		° F.
Alexandria Troas	Asia Minor	150
Lidgah Hammam, near Alexandria Troas	do	140
Diana's Bath, near Smyrna	do	Warm.
Northern extremity of Imolus, near Smyrna	do	140
Tschekgirghé, near Brusa or Proosa	do	113
Kukurtlu, near Brusa or Proosa	do	182
Bademli Baghtsche, near Brusa or Proosa	do	184
Kara Mustapha, near Brusa or Proosa	do	127
Guenzaysma, near Brusa or Proosa	do	113
Kekrout, 5 miles north of Eregli	do	100
Seven miles from Singerli	do	184
Cauvsa	do	125
Hammam Gozi, 12 miles from Osmanjik	do	
Sey Hammam, on Bev Bajar River	do	107
Germish, near Kara Koyunli	do	84
Yanina, or Yapak Hammam, near Kady Keury	do	125
Kirsher	do	113
Flanks of Ginao Mountain	do	Hot.
Beyramitch Valley	do	
Yalova, Coari Hammam, Dagh Hammam (ancient Sergla, or Helanapolis)	do	156
Eski Shehr (ancient Dorylæum)	do	119
Tahta Keupri, 30 miles northwest of Adana on Ak Sou	do	105
Hierapolis, 6 miles from Laodicea	do	130
Bayas		
Bagdad		
Near Kaferdibben, not far from Antioch	Syria	
Springs of Tiberias	Palestine	154
El Hammam, southeast of Galilee	do	115
Baths of Gadara	do	112
Um Keis, at Gadara	do	110
Callirrhöe	do	139
Sirtkamarin (Callirrhöe?)	do	120
Emmaus	do	143
Wady Hamet Abu Dhabhk	do	103
Near Wadi Ghamindel, Hammam Farouni (Pharaoh's Baths)	do	86
Wadi el Ahsa, south of Kerak	do	
Hammam Prusa, on Sinai Peninsula	Arabia	95
Near Muscat	do	116
Ulúju, or Illiji, near Erzroum	Armenia	100
Hassan Caleh, east of Erzroum	do	Hot.
On Khabour River, near Oroomiah	do	105
Erzingau	do	Hot.
Issi Su, near Derik	do	96
Between Khoi and Kolin	do	
Two miles above Mershut, north of Lake Van	do	165
Chaquaranal, near Pilar	do	Boiling.
Ajufral Grande, near Pilar	do	
In Ak Daghlar Mountains, near Musa	do	100
On slopes of Demavend Volcano	Persia	Boiling.
Two miles northeast of Uske	do	84
Abi-garm, 6 miles east of Uske	do	150
East of Uske or Aske on Laur	do	85
On the Laur, one-half mile from Uske	do	82
Near Musratabad	do	75
Near Daulakie	do	Hot.
In Island of Bahrein	Persian Gulf	Tepid.
Anaval, in Khandish	India	120
Sunapdeo, in Khandish	do	
Unapdeo, in Khandish	do	
Veval, in Khandish	do	111
Lakhi, in Sindh	do	104½
Maggar, in Sindh	do	106.2
Musakhet, in the Punjab	do	94
Uch, in the Punjab	do	
Hushangabad, in Malva or Malwa	do	
Sitabari, in Malva or Malwa	do	

Table of thermal springs of Asia Minor and Asia—Continued.

Locality.	Country.	Highest temperature.
		°F.
Pánna, in Bandalkhand	India	
Baidra, in Berar	do	110
Arjana, in the Dehkhan	do	87
Khair, in the Dehkhan	do	87
Lanjabanda, in the Dehkhan	do	91.3
Alvar, in Rajvára	do	
Chittur, in Rajvára	do	80
Jaipur, in Rajvára	do	
Bhadrachelam, in Orissa	do	140
Juggarnath, in Orissa	do	
Hazaribagh, in Bengal	do	
Moughir, in Bengal	do	140
Barari, in Behar or Bahar	do	145
Soorujkoond, near Belcuppe, in Behar or Bahar	do	190
Bhimband, in Behar or Bahar	do	147
Hathbullia, in Behar or Bahar	do	
Kalijhurnia, in Behar or Bahar	do	
Mahuru, in Behar or Bahar	do	
Nunbhil, in Behar or Bahar	do	
Pachet, in Behar or Bahar	do	
Paharpur, in Behar or Bahar	do	114.1
Pinarkun, in Behar or Bahar	do	
Rajgir, in Behar or Bahar	do	
Sitaura, in Behar or Bahar	do	110
Sarguja, in Behar or Bahar	do	186
Tantipara, in Behar or Bahar	do	162
Tautlui, in Behar or Bahar	do	150
Arauli, in the Konkan	do	
Mat, in the Konkan	do	
Rajvari, in the Konkan	do	
Sangameshvar in the Konkan	do	
Savi, in the Konkan	do	109
Turil, in the Konkan	do	
Unali, in the Konkan	do	
Unari, in the Konkan	do	
Vajrabhai, in the Konkan	do	136
Tulsi Sham, in Kattivar	do	124
Soria, in Hindostan	do	108
Kalva	do	
Mahanudi	do	
Painpur, in Kashmir, in Himalayas	do	70
Sheolor, in Kashmir, in Himalayas	do	
Devat, in Chamba, in Himalayas	do	132
Teva, in Chamba, in Himalayas	do	106½
Jauri, in Simla, in Himalayas	do	
Natssa, in Simla, in Himalayas	do	137
Suni, in Simla, in Himalayas	do	135
Badrinath, in Garhval, in Himalayas	do	128.9
Banassa, in Garhval, in Himalayas	do	160
Gaurikund, in Garhval, in Himalayas	do	126.8
Jumnotri, in Garhval, in Himalayas	do	192.6
Kharsali, in Garhval, in Himalayas	do	72.1
Tapuban, in Garhval, in Himalayas	do	
Uri, in Garhval, in Himalayas	do	139.8
Vodri, in Garhval, in Himalayas	do	94.3
Bhatga, in Kulu, in Himalayas	do	
Bihisht, in Kulu, in Himalayas	do	138.6
Kelat, in Kulu, in Himalayas	do	104
Manikaru, in Kulu, in Himalayas	do	202
Nakthan, in Kulu, in Himalayas	do	
Chatargarh, in Kishtvar, in Himalayas	do	
Imla, in Kamaon, in Himalayas	do	
Puari, in Kanaur, in Himalayas	do	125
Chua, in Chahe, in Himalayas	do	110½
Sohora, in Rajauri, in Himalayas	do	
Yeumtong Luchong Valley, in Sikkim, in Himalayas	do	112½
Momay, near Kinjihinjhow, in Sikkim, in Himalayas	do	116
Darjiling, in Sikkim, in Himalayas	do	
Badulla	Ceylon	Hot.
Kitool	do	
Cannea, near Trincomalie	do	106½
Yavi Oota, in Veddah Country	do	
Patipel Aar, south of Batticaloa	do	
Ayer Panas, 10 miles from Malacca	Malay Peninsula	130
Chan-yuen in Shan-Tung*	China	Hot.

* Rev. A. Williams, who gives this locality (*Jour. of the N. China branch of the Roy. Asiatic Soc., n. ser., No. IV, Dec.*, 1867), mentions the following localities of sulphur baths in China, but does not say if they are thermal: Ngai-Shan, Loong-Chuen, Wun-shih-tun, and near Yichow, all in Shan-Tung.

Table of thermal springs of Asia Minor and Asia—Continued.

Locality.	Country.	Highest temperature.
		° F.
Yung-mak, 15 miles from Macao, in Kung-tung	China	Boiling.
Foo-Chow-Foo, in Fuh Keen	do	Hot.
Chung-ling-tow, district of Tsung-fa	do	
Ho-tsing, or Fire Wells, province of Sz'chuen	do	Hot.
At Jeh'-ho in Ch'ahar	do	
In province of Shensi	do	
In province of Chihli	do	
Chutang Chaka	Thibet	166
Peting Chuja (geysers)	do	176
Naisum Chuja	do	183
Dung Chaka (15,000 feet above sea level)	do	130
Ding Nagu Chaka	do	180
Plain of Chang Phing Chuja	do	130
Chajong (Tatapani)	do	Hot.
Pugha	do	174+
Terthapuri, in Guari Khorsum	do	
Shalkar, in Spiti	do	120
Pangmig, in Nubra	do	172.2
Mushkin, in Hasera	do	
Janglung, in Nubra	do	165.8
Chorkonda, in Balti	do	185
Chutron, in Balti	do	111.6
Askoli, in Balti	do	168.8
Chushul, in Pang Kong	do	96
Chagrar, in Pang Kong	do	70½
Kyam, in Pang Kong	do	147
Knarung, in Ladak	do	
Mulbe, in Dras	do	78.6
Bargau, in Gilget	do	
Nilt, in Gilget	do	
Pekar, in Gilget	do	
Chinglong Valley, near Gogra Hoo	Turkestan	140+
Abigarm Kishlak, in Surkham	do	Nearly boils.
Karakash River, above Kushmaidanin Pass	do	130
Shogore, in Chitral	do	
Chang lung (?)*	do	174
Panamik	do	167
Arassan near Ala-kul	do	110
Altyn Arassan,† on Aksu River	do	
Tian Shan Arassan	do	
Arassan, on Kopal River	do	97
Alma Arassan	do	104?
Taragatai	do	
Djungareau Alatau	do	
Kisk Kiol	do	120.2
Near Issar, on River Oxus	do	116
Turkinsk	Siberia	144
Racmanskoi Lake	do	Hot.
Lake Karaulnoe	do	
Lake Gorkoe	do	
Pustoy, on Knilamysh	do	
Baths of Bargusin, Irkutsk	do	
On the Araschan	do	
On the Yablischu	do	
On the Lepsche	do	
On the Irtysh	do	
At head of Abakla	do	
In Baikal Mountains	do	
At Lake Baikal	do	155½
Altai Mountains	do	
Sayone Mountains	do	
Petropaulovky	Kamchatka‡	Hot.

* Probably the same as Chinlong Valley.

† Arassan means warm spring.

‡ In the article Kamchatka, in the Encyclopedia Britannica, it is stated that more than 20 hot springs are known in the peninsula. I can find no enumeration of them anywhere.

CHAPTER VII.

THERMAL SPRINGS OF JAPAN, FORMOSA, MALAYSIA, AUSTRALASIA, AND POLYNESIA.

South of the peninsula of Kamtschatka the Kurile Islands, the Japanese Islands and Formosa form the connecting links between its volcanoes and the intense volcanic centers of the Eastern Archipelago. Each also has its thermal springs, as we would naturally expect. The Kurile Islands have ten volcanoes, but of its springs we have no details. The chain of islands, extending from Bering's Strait to the Antarctic Circle, contains 150 volcanoes, according to Judd,* and if those of the Indian Ocean and the Pacific islands which are adjacent, are added, this system includes half of the active vents of the globe. Here, then, we look for thermal springs, and we are not disappointed. The catalogue we present, however, is but a list of the localities actually known and described. The islands of the Eastern Archipelago have been but partially investigated, and yet we know that its volcanic ranges abound in hot springs, although the localities cannot be specified, the majority of travelers merely mentioning the fact of their existence without any details, omitting, in most cases, both names and temperatures. The interior parts of many of the islands also have never been visited, and of the smaller islands a large number have not even been touched by the explorer's feet. It will not, therefore, be surprising if future investigation should add immensely to the catalogue of springs that we present in connection with this chapter.

From Japan to Formosa† the volcanic band turns to the westward, and the proximity of the island to the Chinese coast may account for the springs near Macao and Foo-chow-choo in China.

Between the continent and the islands of Borneo, Java, and Sumatra a shallow sea exists. Borneo is not volcanic, and, as far as known, has no thermal springs, the line apparently passing to the westward through the Celebes.

JAPANESE THERMAL SPRINGS.

As just mentioned, Japan is considered as one of the links in the volcanic band that extends from the Aleutian Islands through Kamtschatka and Formosa southward to the islands of the Eastern Archipelago, where it widens out very considerably. Japan has twenty-five volcanoes,‡ and is said to have veritable geysers; but I can find no description of any that are more than pseudo-geysers. Our knowledge of the interior of Japan, however, is exceedingly limited. Boiling springs are found at Urijnio, Ussina, and Wunzen.

The following lists of Japanese springs are from the reports of Benjamin S. Lyman, who has surveyed the oil lands of Japan:

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* Formosa is subject to frequent earthquake shocks.

†Volcanoes, &c., by John W. Judd, New York, 1881, p. 230.

‡From the fifth century to the nineteenth, one hundred and forty-nine destructive earthquakes are recorded in Japan.—Trans. Asiatic Soc. of Japan, Vol. VI, Part II, 1878, p. 271.

Thermal springs in the southern part of Yesso.

Names.	No. of springs.	Temperatures.
		°F.
Oil Lake	1	210.
Nuburibets	5	118 to 210.
Jōzan	9	177 to 192.
Obune	4	154 to 173.
Isoya	5	118 to 161.
Nigorikawa	4	120 to 134.
Esan	3	113 to 127.
Kakumi	3	104 to 122.
Yunai	3	114.8 to 121.
Kusuri (lower)	1	113.9.
Yudomari	4	81½ to 91.4.
Kusuri (upper)	1	95.
Shikabe	5	120 to 195.8.
Yumoto	3	109.
Yunosawa	2	89½ to 109.
Yurap	2	95 to 102.
Yunokawa	1	95.
Boro	2	80½ to 91.4.
Tomi	1	122.
Kamiyunosawa	1	86.

The following is a list of the springs visited by Mr. Lyman in 1876, and they are chiefly in Shinano and Echigo:

Names of villages.	No. of springs.	Temperatures.
		°F.
Sakamoto	4	95 to 102.
Yamanoyu	1	114.8.
Bessho	9*v*	107.6 to 114.8.
Yazawa	2	102 to 104.
Kutsukaka	1	96.8.
Asama	11*v*	104.9 to 127 4.
Yunohara	5*v*	82.4 to 107.6.
Yumoto	2*v*	156.2 to 163.4.
Yunosawa	4	107.
Yunoshiki	3	114.8 to 145.
Kanebara	1	95.

v At these localities there are volcanic rocks.

Mr. D. H. Marshall, in an article on the Volcanic Mountains of Japan (Transactions Asiatic Society of Japan, Vol. VI, Part II, 1878), gives the following hot spring localities:

Hot baths of Ashinoyu, Ubaga, and the Hayakawa Valley, near the base of Fuji, or Fuji-san, Kusatsu.

Sawatari, near Asama and Shirane-san.

Yumoto Shionoyu, near Shirane-yama.

Kawajin, near the base of Nasuyama, has hot bath.

On the island of Shikoku.

At the base of Onsen (or Wunsen), on Kinshiu Island.

On pages 346 and 347 of the same volume of the Transactions, Mr. Edward Dewey gives the following temperatures of hot springs at Kusatsu:

	° F.
Netsu-no-yu	148+
Jijo	145+
Goza	150+
Take	150+
Nagi	114+

These springs, he says, are in the center of the village, and at Ichuya near by; the temperature is 109° F. to 113° F.

At Ikao, near Kusatsu, there are springs with temperatures of 104° F. to 113° F.

At Shimonosawa there are very hot springs; also at Onogawa, Akayu, and Go-hiki, in Okitama. (*See Vol. III, Part II, Trans. As. Soc. of Japan.*)

The hot springs of Yomotz and Atami are on a peninsula of Niphon, southeast of the noted volcano of Fusi-yami.* The springs of Atami are intermittent in action, and, according to Sir Rutherford Alcock, are not very regular in their spoutings, which occur about six times daily (*i. e.*, in 24 hours), varying, however, on different days. An immense volume of steam and slightly sulphureted water is ejected, but the hours are not at all regular.†

FORMOSA.

The thermal springs of Formosa have been but partially examined; those of Tamsuy, or Tamsui, in the northern part of the island, being best known. They are sulphur springs—seven or eight apertures of active springs being scattered over an area of about two acres. They are variable in activity, and the steam rushes out like steam from a boiler. Some of the springs are said to be in continuous action, spouting to the height of 2 feet or more, and would appear to be what we have called pseudo-geysers in the Yellowstone National Park. This locality is not the only one existing in Formosa, although the one oftenest mentioned by travelers.

MALAYSIA, OR THE EASTERN ARCHIPELAGO.

Different authors assign different limits to the Eastern Archipelago; but for our purposes it is sufficient to include those islands lying between New Guinea and the Asiatic continent under this head. New Guinea might also be included; but, so far as known, it is without thermal springs.

This Malaysia, Indian or Eastern Archipelago, as it is variously named, is the greatest volcanic center on the globe. The focus of volcanic activity is considered by Judd to be in the islands that lie between Borneo and New Guinea. From the center thus indicated radiate several volcanic lines, one of which, extending northward, we have just considered. One extends westward, through the islands of Java and Sumatra, and up the coast of Malayan India; and another reaches eastward as far as the Elizabeth Islands, with a branch southward, through New Zealand, to South Victoria, on the Antarctic Circle. Of the group of islands to be considered, Celebes, Java, and Sumatra are most noted for their thermal springs.

The "Banos" of Luzon, in the Philippines, have, however, been probably the oftenest described.

The zoology of the islands of the Eastern Archipelago is much better known than the geology; although, in the past few years, much has been added to our knowledge in the latter branch of science.

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* The last eruption of Fusi-yami was in 1707.

† Jour. Geograph. Soc., 1861, p. 321, 56.

THE PHILIPPINE ISLANDS.

Thermal springs are known on the islands of Luzon and Mindanao, Sir John Bowring* giving two localities on the latter.

The celebrated "Los Banos" on Luzon, near Manila, include about a dozen springs; the highest temperature, according to Clarke Abel, being 180° F.† James D. Dana, of the United States exploring‡ expedition, gives a temperature of 178°, and says they were once a fashionable resort, but when he was there were only used by washerwomen and to take feathers from fowls. He says, also, that they were the only evidence of volcanic action in what was once the scene of extensive activity. In 1863, however, the town of Manila was destroyed by an earthquake, and nearly 2,000 people perished. What the effect was upon the springs, we do not know.

H. N. Moseley, one of the naturalists with the Challenger expedition, mentions the occurrence of hot springs on Camiguin Island, 80 miles east of Cebu, with a temperature of 145° F.

THE MOLUCCAS.

In the Moluccas, the islands of Batachian, Ceram, and Banda are known to have hot springs; Batachian having geysers also.§ The latter is a volcanic island, and the surrounding region is an extensive theater of volcanic action. Those islands that are not *per se* volcanic are shaken by earthquakes which have their origin in the neighboring islands.

CELEBES.

The hot springs and geysers of Celebes are on the peninsula of Minhassa, which is at the north end of the island; and are comparatively well known, having been described in considerable detail by a number of travelers, especially by Bickmore,‖ and Wallace.¶ The following are brief descriptions of the principal localities:

Lake Linu is in the basin of an extinct crater on the slopes of Mount Klabat, a volcanic cone, at the base of which is a village called Ayer-Madidi, or "Hot Water." The lake is about half a mile in diameter, filled with bluish and bluish-white water. At the north end of the lake is a huge solfatara, from which there is a copious escape of sulphurous gas.

Langowan.—Near Langowan is an almost circular spring measuring 48 feet in diameter, from which steam escapes in great quantity, the water of which has a temperature of 172°.4 F.

At *Nolok* is a similar spring, bowl-shaped, measuring 75 feet across and 20 feet in depth, with sides of soft clay. The stream flowing from this basin has a temperature of 123°.8 F., and the water is opaque. When the stream that flows into the basin is swollen by heavy rains, the spring is said to have eruptions in which the water is thrown 50 feet into the air. It is, therefore, a geyser.

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*A Visit to the Philippine Islands, 1859.
†Narrative of a Journey in the Interior of China, &c., 1818.
‡U. S. Exploring Expedition, Geology.
§The Eastern Archipelago, by W. H. Davenport Adams, p. 362.
‖Travels in the East Indian Archipelago, 1869.
¶The Malay Archipelago.

THE MUD WELLS AND SPRINGS OF TOMPASSO.

The most celebrated locality in the Celebes is near *Tompasso*, where there are mud wells and boiling springs. The mud springs are a mile and a half from Tompasso, and described by Bickmore* as occupying an area of about half a mile square on a gentle declivity. The principal well is triangular, measuring 30 feet on each side. The mud is lead-colored, thin in the center, and becoming thick towards the edges.

> The distance between the centers of these ebullitions varies from six inches to two feet or more, so that the whole surface is covered with as many sets of concentric rings as there are separate boiling points. Near each of these centers the rings have a circular form, but as they are pressed outward by the successive bubbling up of the material within them, they are pressed against each other and become more or less irregular—the corners always remaining round until they are pressed out against those which originated from another point. By that time the rings have expanded from small circles into irregular polygons.

Near this mud well is a boiling hot spring 3 feet in diameter and 2 feet in depth, in which the water had a temperature of 208°.4 F. The natives use it for washing their clothing. Some of the springs, of which there are at least 20 on the hillside, are true geysers. At the foot of the hill there is a sulphur lake and mud pond. The description of these springs given by Mr. Wallace† is as follows:

> A picturesque path leads to a beautiful circular basin about forty feet in diameter, bordered by a calcareous ledge, so uniform and truly curved that it looked like a work of art. It was filled with clear water very near the boiling point, and emitted clouds of steam with a strong sulphurous odor. At one point it overflows and forms a little stream of hot water, which, at a hundred yards distance, is still too hot for the hand to endure it. A little further on, two other springs in a continual state of active ebullition, appeared to be much hotter; and at intervals of a few minutes a great escape of gas or steam occurred, throwing up a column of water three or four feet high.

JAVA.

Java has been well named the "Land of Fire." Michelet, in his Mountain, says it is dowered with fire. The island is 630 miles in length, and from 35 to 126 miles in width, having an area almost two-thirds that of Great Britain. It has extending through its length two lines of volcanic mountains, with from thirty-eight to forty-five volcanoes whose heights are from 3,000 feet to nearly 12,000 feet, and whose eruptions instead of being lava are torrents of mud like some of the South American vents. They are, therefore, mud volcanoes on the grandest scale. In the crater of one of the volcanoes (Taschem) is a lake, strongly impregnated with sulphuric acid, from which issues a stream so acid that no form of life can exist in it nor in the sea near its mouth. Near another (Batan, an extinct cone) is the famous Guevo Upas (Vale of Poison) so filled with an accumulation of carbonic-acid gas as to be fatal to life.

Hot springs abound in Java, especially along the volcanic mountains, and the following are descriptions of but a few:

The Valley of Dieng.

The valley of the Dieng measures about a mile in circumference, surrounded by a semicircle of irregular hills in the Brambanan Mountains.

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*Travels in the East Indian Archipelago, p. 359.
†In the Malay Archipelago, p. 258.

It is marshy, and scattered over its surface are the ruins of ancient Buddhist temples. The following are the springs at or near Dieng:

Tologo Leri or *Lin* (water in which rice has been washed) is a caldron filled with milky water constantly bubbling and giving off steam.

Chondero di Moeko or *Mocko* is a pool of boiling water about 20 feet in diameter, in the center of which are three or four jets of scalding water, which spout variably to the height of 4 or 5 feet. The banks of the pool are of soft, hot sulphurous mud.

Talogo Warno is about a mile from the Dieng, and is a small lake in which the waters are said to be of many colors. "A bright yellow at one part and an emerald green at another; here a beautiful azure, and there a delicate rose; then orange and milky white—all these hues blending and merging into one another as softly and gradually as the tints of a humming-bird's plumage."*

Kawa Kiwung is a hot, muddy valley between the Brambanan and Modrodo, in which there is said to be another spring that is in constant ebullition, sending up tall columns of water, but to what height is not stated.

Springs at Bongas Village.

The hot wells of Bongas Village in Java, are on a gently inclining plain which is perfectly white from the spring deposits, and occupy an area measuring about 100 yards in circumference. Sulphurous vapors rise from it, and the water comes from several apertures, the hottest temperature being 130° F. The deposits are mainly calcareous and coat shrubs and branches exposed to the water.†

Mud Springs.

Mud springs, called *Bledeg* by the natives, are mentioned by Dr. Horsfield as being situated between Grabogan and Blera, on a plain, covering an area of half an English mile. The explosions are said to be more violent during the rainy season. In temperature the springs are lukewarm.

The following description is by Dr. Horsfield:

> About the center of the limestone district is found an extraordinary volcanic phenomenon. On approaching the spot from a distance it is first discovered by a large volume of smoke, rising and disappearing at intervals of a few seconds, resembling the vapors arising from a violent surf, whilst a dull noise is heard like that of distant thunder. Having advanced so near that the vision was no longer impeded by the smoke, a large hemispherical mass was observed, consisting of a black earth, mixed with water, about 16 feet in diameter, rising to the height of 20 or 30 feet in a perfectly regular manner, and, as it were, pushed up by a force beneath, which suddenly exploded with a dull noise and scattered about a volume of black mud in every direction. After an interval of two or three, or sometimes four or five, seconds the hemispherical body of mud or earth rose and exploded again.

SUMATRA.

In Sumatra the volcanic line so prominent in Java is continued, with the direction changed, *i. e.*, to the northwest, and it extends to the Nicobar and Andaman Islands. As in Java, the thermal springs are

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*The Eastern Archipelago, Adams, p. 71.

†Essay on Mineralogy of Java, by Dr. Horsfield, in Vol. IX, Batavian Trans., quoted in History of Java by Sir Thomas S. Raffles.

found in connection with the volcanic range, especially at the base of Berapi, a volcano over 12,000 feet in height. The other localities of which I find mention made, are included in the accompanying catalogue.

AUSTRALASIA.

Australia, so far as known, has no volcanoes, nor has it any thermal springs. A fossiliferous, siliceous deposit has been found in New South Wales which answers in appearance to geyser-sinter. The region is volcanic, and geysers may once have existed there. To the northeast and east, however, in the island of New Britain, the Solomon Islands, New Hebrides, and New Zealand a branch of the volcanic line is continued from the Eastern Archipelago, and on this line thermal springs are found, as our catalogue indicates, New Britain, Great Banks and Santa Maria Islands, the New Hebrides, and New Zealand all having springs of high temperatures. The noted localities of New Zealand have been described in Chapter II, and no further description is necessary. The catalogue shows that besides the geyser areas the North Island has several other spring localities, and that the South Island is not without its thermal springs.

POLYNESIA.

Under this head I will simply refer to the springs of the Fiji Islands and of the Sandwich Islands. The former might perhaps be included under the head of Australasia, as they lie but a short distance east of the New Hebrides.

Fiji Islands.—The thermal springs of the group are found on three of the islands, those of Savu-Savu on Vanua Levu being the most noted. They are found in two places, and extend for half a mile along the shore, some springs bubbling up through the salt water below high-water mark. The three principal springs are in a circle or basin of 150 yards by 40 yards, which is 9 feet above high tide. They are intermittent, the highest spouting 2 or 3 feet into the air. The water is saline and gives off a slight sulphurous odor. Formerly there were fifteen springs, and they were much used as kitchens, especially for cannibal feasts, one of the springs in particular being used as a caldron. Miss C. F. Gordon-Cumming says that in 1863 a chief captured the old woman who owned these springs, and also sixteen men.

She was past seventy, and must have been very tough and smoke-dried, but as in her younger days she had been a regular Joan of Arc, leading her tribe to battle, and herself fighting hand to hand with a hatchet, he determined to eat her. So he had her cooked with the sixteen men, and made a great feast, and then, to spite the people, before leaving the district he attempted to choke up all of the springs, in which amiable effort he partially succeeded. These springs were also a favorite place for depositing all superfluous babes, especially girls, who never got much of a welcome. They were popped in alive like so many lobsters, and treated with quite as little ceremony.

The rocks near the springs are basalts and trachytes, but there is at present no active volcano in the group.*

Other spring localities are found on Vanua Levu and the other islands. They are enumerated in the table.

Sandwich Islands.—The islands are somewhat isolated, and, according to Judd, form an exceptionally situated volcanic group. Its volcanoes are unsurpassed in height and bulk by those of any other portion of the world. The cones rise to a height of 14,000 feet, while the sea around

* Volcanoes, p. 237.

them has a depth of 2,000 to 3,000 fathoms. The few thermal springs that are found, according to Dana, are not very hot. They occur on the island of Hawaii.*

We have now traced the occurrence of thermal springs around the globe, and find no quarter without some thermal development. Each appears to have its geyser region. America has the geysers of the Yellowstone National Park; Asia a geyser region in Thibet; while the Iceland geysers may be considered as belonging to Europe, and the New Zealand field to Australasia. Africa seems to be left out, and yet the comparatively unimportant geyser area of the Azores may perhaps be considered as its geyser region.

Table of thermal springs of Japan, Formosa, Malaysia, Australasia, and Polynesia.

[For lists of authorities for all except New Zealand see Bibliographical Appendix I, and for New Zealand see C.]

Locality.	Country.	Highest temperature.
Hot and warm springs	Kurile Islands	
Near Shiravi, in Yesso	Japan	Boiling.
On the Osubetz, in Yesso	do	136
In the southern part of Yesso	do	*210
Shinano and Echigo	do	*163.4
Hot Sulphur Springs of Atami	do	120
Yomotz, north of Atami	do	
Hot Springs of Ussina, in Niphon	do	212
Urijnio	do	Boiling.
Wunzen or Onsen Kinshiu	do	Boiling.
Near Kusatsu	do	150
Hot Sulphur Springs of Tam-sui	Formosa	Boiling.
Los Banos, near Manilla, island of Luzon	Philippine Islands	180
Los Banos, on the island of Mindanao	do	182
Pueblo of Mainit, island of Mindanao	do	
On island of Camiguin, 80 miles east of Cebu	do	145
Hot springs and geysers on island of Batachian	Molucca Islands	Hot.
Hot springs on island of Ceram	do	Hot.
Hot springs on island of Banda	do	Steam, 250
Geysers and hot springs of Lahendong	Celebes	202
Lake Linu, near Lahendong	do	
Between Tomohou and Taiduno	do	
Langowan	do	172.4
Passo	do	Hot.
Hill of Timpang	do	
Geysers near Nolok	do	Boiling.
In crater of Raño Assem	do	
Mud wells near Tompasso	do	
Hot spring near Tompasso	do	208.4
Hot wells of Batu	Java	108
Singorth, near Batoe	do	Hot.
Near Dieng, at Lake Chondero di Moeko	do	Boiling.
Tologo Leri (water in which rice has been washed)	do	
Tologo Warno, near Dieng	do	
Kawa-Kiwung geysers	do	Boiling.
Bongas Village	do	130
Bledeg (mud springs), between Grabogan and Blora	do	Lukewarm.
Near volcano of Tankuban Prahu	do	112
Between Dusum Tanjong and Dusum Simpang	Sumatra	120
At the base of Berapi	do	
At Priañgau	do	Hot.
On river Abu or Ager Grau	do	Hot.
On island of New Brittain		Hot.
Near Port Resolution, Isle of Tanna	New Hebrides	190
Great Banks Island, Vanua Lava	do	Boiling.
Santa Maria	do	Boiling.
Savu-Savu on Vanua Levu	Fiji Islands	210
Wainum on Vanua Levu	do	Boiling.
Loma Loma on Vanua Levu	do	
On island of Ngau	do	Hot.
At Wai Mbasanga, on Viti Levu Island	do	
South of Waimate, 15 miles west of Bay of Islands, Auckland, North Island.	New Zealand	154
Taiaimi, near Bay of Islands, Auckland, on North Island	do	Warm.
Waieri, 4 miles west of cone of Turoto, Auckland, North Island.	do	168

*Report U. S. Expl. Expedition, volume on Geology, by J. D. Dana.

Table of thermal springs of Japan, Formosa, Malaysia, &c.—Continued.

Locality.	Country.	Highest temperature.
		° F.
Waiwera, Auckland, North Island	New Zealand	Hot.
Near Mahurangi, Auckland, North Island	do	110
West side Waikato River, 4 miles from Lake Waugape, Auckland, North Island.	do	200
Te Puia, near Lake Wangape, Auckland, North Island	do	168
Geysers of Taupo Rotorua, &c., Auckland, North Island	do	†215
Hammers Plains, Nelson, South Island	do	
Head of Lake Sumner, Canterbury, South Island	do	
Kailua, on Hawaii	Sandwich Islands	Warm.
Kowaihae, Hawaii	do	
Near Kapoho Point, Hawaii	do	

* For detailed catalogues see Japan in preceding pages.
† For complete catalogue of springs of this region, see table at end of Chapter II, this part of report (I.)

PART III.

THERMA-HYDROLOGY.

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INTRODUCTION.

For the general title of this portion of my report I have combined the words *thermal*, hot or warm, and *hydrology*, the science of water, into *Thermahydrology*, as the best general term to include the remarks made in the following chapters. I am well aware that this part of my report is not exhaustive, but the remarks that are made may suggest some lines of investigation that can be followed in the future. The preliminary work in the Park has now been done. Charts are made on which the individual springs are enumerated, so that what remains to be done is to have careful observations made with a view of determining, if possible, the laws governing the action of the various geysers. Protracted observations in detail carried through several successive seasons are necessary to obtain even an approximate idea of these laws. It is to be hoped that an opportunity for this kind of work will be afforded before long. The example of New Zealand might be followed and medical officers appointed, as in the Rotorua district, where also hospitals and laboratories have been established.

SECTION I.—GENERAL FEATURES.

CHAPTER I.

DEFINITION OF THERMAL SPRINGS—SOURCE OF WATER—OUTFLOW—LIFE IN HOT SPRINGS—DISTRIBUTION.

In the first place we have to inquire what thermal springs are and whence they derive their supply of water; next to consider their outflow, the life which they contain, and their distribution over the globe.

DEFINITION OF THERMAL SPRINGS.

Thermal springs strictly considered are those whose mean annual temperature exceeds the mean annual temperature of the locality in which they are found. This, of course, includes more than the springs that are usually called warm or hot, for if the temperature exceeds, no matter in how small a degree, the mean temperature of the place in which it rises, it is truly a thermal spring. There will, of course, be a variation according to geographical position. Thus a spring which is warm in Siberia, where the ground is frozen to the depth of 630 feet, would be a cold spring in the West Indies, or in the Eastern Archipelago. In the catalogues of Part II the lowest temperature given, with one exception, is 60° F. Very few springs below 75° F. are, however, included, most of them ranging from the latter temperature to the boiling point, and it is to springs of this range in temperature that we here refer. The one exception noted above is in Alaska, a spring of 33° F. being included in the table. When this temperature was taken the air was 13° colder than the spring. According to Walton waters of 70° to 85° may be termed temperate; from 85° to 92° F., tepid; from 92° to 98° F., warm; and all above 98° F., hot.

The following springs are given by Adolph Erman,* but were not included in the table of Siberian springs:

Location.	Temperature of the air.	Temperature of springs.
	° F.	° F.
Springs at Slatoust, Siberia	.....	+42
Springs at Aleshki, Siberia	+18.5	+32.11
Springs at Tomsk, Siberia	−10.6	+33.12
Springs at mouth of Uda, Siberia	− 2.8	+35.4
Springs near Ust Kiakhta, Siberia	.....	+35.2
Springs near Irkutsk, Siberia	−19.7	+38.7
In the mines of Achinsk, Siberia	.....	+36.5

The springs in this list never freeze. They were not included in the table on page 344, as I do not know what their mean annual temperatures are, nor the mean annual temperatures of their localities. They are, however, probably true thermal springs.

SOURCE OF WATER IN SPRINGS.

The source of water found in springs was long a puzzling question to philosophers. Aristotle taught that there were large cavities in the interior of the earth filled with air, and that this air condensed to water on the cold roofs, and made its way to the surface through fissures.

* In Travels in Siberia, by Adolph Erman. London, 1848.

Vitruvius believed that springs were due to an accumulation in subterranean reservoirs of rain and melted snow. Descartes imagined that the source of the water was the sea, from which water flowed into subterranean caverns, was vaporized and afterwards condensed, finally escaping to the surface through crevices in the rocks. Mariotte and Halley independently demonstrated that the fall of water in the form of snow, rain, and dew is sufficient to account for all the water of rivers and springs.* There may also be some truth in the idea of Descartes, and certain springs may be due to communication with the ocean.

That rain water does penetrate to considerable depths and supplies springs is proved by the fact of the constant presence in mines, of water that comes from above the galleries and drips from their roofs. In Misnia, in Saxony, it has been known to form in drops on the roof of a mine 1,600 feet deep,† and it is well known that after prolonged droughts numerous springs become weak and many cease to flow, but are revived after heavy rains.‡ It is a fact also that where springs exist there is usually higher ground somewhere in the neighborhood, from which the water may and probably does flow.§

In some places water may be forced to the surface by gases, and in very hot springs no doubt the steam generated by the contact of the water with the heated rocks below is a potent agency in forcing water to the surface, but it is a well ascertained fact that the waters of springs are meteoric in their *origin*.

OUTFLOW OF SPRINGS.

None of the springs or geysers in the Yellowstone National Park have been gauged so that we have no exact data as to the amount of water flowing from them. In the case of the geysers the flow is usually only during the period of activity,‖ and in the case of most of the ordinary springs of the Park the overflow is probably less than would be expected.

This will, however, have to be a subject of future investigation. It will be interesting, however, to note the amount of water poured out by well known springs that have been gauged. Le Coq says a million of litres (200,000 gallons) is no unusual quantity of water to be poured from a spring, and he says that of 500 springs in Central France, 231 have been gauged and yield 2,628,000 gallons every twenty-four hours.

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* Buffton also demonstrated it by selecting a lake without any outlet and showing that the evaporation from its surface was equal to all the water that flowed into it. (*See page* 51 *of Physical Geography*, by A. Barrington.)

† *Ibid*, page 44.

‡ During the very dry season in August and September, 1881, the anthracite coal mines in Schuylkill County, Pennsylvania, had to depend largely upon the supply of water found in the mines.

§ It is interesting in this connection to compare the elevation of Yellowstone Lake in the National Park with the two geyser areas of Fire Hole River:

	Feet.
Yellowstone Lake has an elevation of	7,738
The Lower Geyser Basin has an elevation of	7,236
The Upper Geyser Basin has an elevation of	7,372

The geyser basins are also in valleys with high plateaus surrounding, which is the case also with the other areas of the park, as the Shoshone Basin, Heart Lake Basin, Hayden's Valley Springs, &c., while the lake has a high mountain range on the east side and a high plateau on the west.

‖ According to Mr. C. H. Wyman the eruptions of the "Excelsior Geyser" double the volume of the Fire Hole River, which, at this point, is 2 or 3 feet deep and nearly 100 yards wide, and render it too hot to ford for a long distance. (*Report of P. W. Norris, superintendent Yellowstone National Park*, 1881, *p.* 55.)

Judd, in his "Volcanoes," says that 180,000 gallons are poured daily from the Bath Spring in England.

The following table shows the outflow of a number of American springs:

Name of springs.	Number of gallons per minute.	Authority.
Warm Springs, Bath County, Virginia	6,000	Walton's Springs of the United States and Canada.
Warm Springs of Georgia	1,400	Do.
Lebanon, New York	500	Do.
Arkansas Hot Springs	360	Do.
Sulphur Springs, Middle Park, Colorado	200	Do.
Geyser Spring, Ojos Calientes, New Mexico	50	Dr. Loew, Vol. III, report United States Geographic Surveys West of 100th Meridian.
Las Vegas, New Mexico	15	Do.
Warm Springs, Madison County, North Carolina	9	Walton.
Carlisle Spring, Colorado	8	Dr. Loew.

It can readily be seen that the amount of heat taken from the earth through the agency of warm and hot springs, which are continuous in their action, must be enormous.

LIFE IN HOT SPRINGS.

One of the most interesting subjects in connection with thermal springs is the presence of animal and vegetable life in waters that are hot. There is a wide field for investigation in this particular, and the Yellowstone National Park will be a most favorable place in which to carry it on, both on account of the numbers of its springs and of their great range in temperature. So much time has had to be taken up with mere preliminary work that, as yet, little has been done in this direction.

Animal life.—The only instance of the presence of animal life in the hot springs of the Yellowstone Park yet noted is the discovery in 1872, by Mr. W. R. Taggart, one of the geological assistants of the survey, of larvæ of *Helicopsyche* in water having a temperature of 108° F.

Instances of animal life in warm springs of other places are as follows:

Mrs. Partz saw in springs in Owens Valley, California, a spider-like animal and small red worms in water having a temperature of 124° F.*

On the Pacific plains, in Tehuantepec, between the passes of Tarifa and Chivela, the United States exploring expedition in 1872 found fish in springs of 94° F. temperature. Cattle also drank this water; and in springs in the Pass of Chivela fish were found in water that was at 98° F.

According to Mr. James Richardson† the springs of Ghasa and Toser in Morocco, have fish in water that has a temperature of 95° F., and turtles live in the warm springs near Utica.‡

Vegetable life.—The presence of vegetable life in warm and even in very hot waters is of frequent occurrence in all regions of warm and hot springs, the bright green confervoid growths being common in thick

*See American Journal of Science and Arts, Vol. 46, 2d series, p. 31.

† Travels in the Great Desert of Sahara.

‡ Fish have been ejected from volcanoes. According to Lyell (Principles of Geology, p. 348), so great a quantity of fish were ejected from the volcano of Imbaburu, in the Andes, in 1691, that prevailing fevers were attributed to the effluvia from the putrid animal matter.

masses in springs of comparatively low temperatures, viz, of 100° F., or less.

At the Healing Springs of Bath County, Virginia, in water of 85° to 88° temperature, a green moss-like growth a couple of inches in length forms with great rapidity on the walls of the reservoirs, pools, and baths, and is used as a dressing for ulcerated surfaces.*

In the small stream, which is supplied by the springs of San Bernardino, California, according to Prof. W. P. Blake,† the water has a temperature of 130° F., and is filled with dense masses of bright green *confervoids.* Near the edge of Gardiner's River, in the Yellowstone National Park, below the Mammoth Hot Springs, similar growths to those just mentioned are found in water of 132° F. temperature. At the Lewis Lake Springs, Taggart, in 1872, found that springs of temperatures of 120° F., and less, were covered with a leafy vegetation, while those above that temperature were covered with a growth of fungoid pulp.

At numerous places in all the geyser areas and at Gardiner's River, in the Yellowstone Park, masses of gelatinous material of greenish, red, yellow, and brown colors are noticed, and usually have been considered as of organic origin. In most cases, where microscopic examination has been made, no trace of vegetable organization has been noted, and in regions where the springs are siliceous this curious material is probably that form of gelatinous silica described in another place under the name of *viandite.*

In some springs of very low temperatures a brown, leathery-looking material is found lining the basins. It becomes hard upon drying, but has never, as yet, been examined microscopically or chemically, so that its nature is unknown; but in all probability it is one of the forms of silica, rather than an organic material.

Among some of the material collected in 1871, Dr. Billings recognized *Palmellæ* and *Oscillariæ* in vegetable matter from Gardiner's River Springs,‡ and in the mucilaginous deposit from the sides of a spring, which had a temperature of 197° F., in the Lower Fire Hole Basin, Dr. Curtis, in 1872, found skeletons of diatoms, but no living specimens.§

At the geysers of California, on Pluton Creek, Prof. W. H. Brewer found algæ in water of 200° F., and at 112° F. layers 3 inches in thickness were formed. He also found *confervæ* in water of 140° F. to 149° F. Dr. James Blake also found *confervæ* in temperature of 198° F. at the same locality and *oscillatoriæ* and diatoms in water of 174° F. At the Pueblo Hot Springs, in Humboldt County, Nevada, Dr. Blake collected fifty species of diatoms in water of a temperature of 163° F.‖ At Benton Spring, Owens Valley, California, algæ grow at 160° F., and cease below 100° F.¶

The following are some of the observations that have been made in foreign localities:

At Nolok, in Celebes, algæ grow in water of a temperature of 123°.8 F., and at Langowan, on the same peninsula, a small stream formed by the overflow of the springs has a temperature of 170° and contains algous growths.**

At Camiguin, an island 80 miles east of Cebu, Mosely, one of the

* Walton's Mineral Springs of the United States, &c., p. 325.
† Explorations for a Pacific Railroad Route, Vol. V, p. 63.
‡ Report United States Geol. Survey for 1871, p. 70.
§ Report United States Geol. Survey for 1872, p. 231.
‖ Dana's Manual of Geology, p. 611.
¶ Amer Jour. Sci. and Arts, vol. 46, 2d series, p. 31.
** Bickmore's Travels in the East Indian Archipelago.

naturalists on the Challenger, found algæ at 113½° F., and says that *Oscillotariæ* have been found in water of 178° F. to 185° F. At Banda Island he found a white gelatinous algæ at 140° F.* [Might not this have been, in part, at least, gelatinous silica.]

Sir Jos. Hooker mentions the presence of algous growths in the Momay Springs, in the Himalayas, in India, where the temperature is 110° F., and at Soorujkoon in water of 158° F., and at Pugha, in Thibet, at 174° F.†

Professor Dana found feathery confervæ in Luzon, at the springs where the temperature was 160° F.‡

THE DISTRIBUTION OF THERMAL SPRINGS.

A single glance at the preceding portion of this report will show the wide extent of the distribution of warm and hot springs. With the exception of Australia, none of the continents is without them.§ Latitude has no effect, for we find them equally hot in the Arctic regions and under the equator. Thermal springs, in the strict sense of the term, are universal in their distribution. Of course, *hot* springs are less widely spread over the globe, while veritable geysers and spouting springs are still more limited in their occurrence, and yet they are confined to no particular quarter of the globe, as we have seen. Iceland, the Azores, Thibet, New Zealand, and our own Yellowstone National Park are the world's geyser areas as known at the present time. The connection of boiling springs with the volcanic regions of the world will be referred to in a succeeding chapter.

Thermal springs are found at all elevations, and the following table, although by no means complete, will give a good idea of their range of elevation:

	Elevation, in feet above sea level.
Island of St. Paul, in Indian Ocean	0
Savu-savu, on Vanua Levu	9
Ems, in Germany	291
Wiesbaden, in Germany	323
Aix la Chapelle, in Germany	400+
Haukadal geysers in Iceland	900
Bourbonne, in France	900
Schlangenbad, in Germany	900
Soufriere of St. Lucia, West Indies	1,000
Lebanon, New York, United States	1,000
Springs near Rotorua Lake, New Zealand	1,043
Springs near Rotomahana Lake, New Zealand	1,088
Springs near Lake Taupo, New Zealand	1,250
Hot Springs of Arkansas, United States	1,360
Plombieres, in France	1,400
Santa Barbara, California, United States	1,450
Mariana, Venezuela, South America	1,465
San Bernardino, California, United States	1,618
Warm Springs, North Carolina, United States	1,700
Warm Springs, Georgia, United States	1,800
Bagneres de Bigorre, in France	1,800
Bagneres de Luchon, in France	2,000
"Petite Soufriere of Dominica, West Indies	2,000

* Notes by a Naturalist on the Challenger.

† Himalayan Journals.

‡ Dana's Manual, p. 612.

§ In the Richmond River in New South Wales, Prof. A. Liversedge has found a siliceous deposit, which he says answers to sinters and geyser deposits. They are found in a basaltic and trachytic region. (Jour. R. Soc. N. S. Wales, Vol. X, p. 237–239.) This would seem to indicate the former presence of hot springs on geysers in New South Wales, where none exist now.

	Elevation, in feet, above sea-level.
Pfeffers, in Switzerland	2,128
Onoto, Venezuela, South America	2,161
Boiling Lake of Dominica, West Indies	2,400
Gastein, in Germany	3,520
Near Salt Lake City, Utah, United States	4,320
Leuk, in Switzerland	4,600
Hot Springs of Lake Tahoe, California, United States	6,500
Lower Geyser Basin, Yellowstone National Park, United States	7,236
Upper Geyser Basin, Yellowstone National Park, United States	7,372
Rustic Group, Heart Lake Basin Yellowstone National Park, United States	7,475
Gibbon Basin, Yellowstone National Park, United States	7,527
Mud Volcanoes, Hayden Valley Yellowstone National Park, United States	7,723
Hot Springs, Yellowstone Lake, Yellowstone National Park, United States	7,738
Hot Springs, Lewis Lake, Yellowstone National Park, United States	7,800
Shoshone Geyser Basin, Yellowstone National Park, United States	7,825
Sulphur Springs, Middle Park, Colorado, United States	8,000
Dona Ana, Chili, South America	10,000
Yeumtong in the Himalayas, India	12,000
Momay Spring in the Himalayas, India	16,000
Geyser region of Lake Tengri Nor in Thibet	16,000

CHAPTER II.

GEOLOGICAL FEATURES.

Geological position.—When thermal springs are considered in their widest signification, it will be found that they are not confined to any one geological formation. When, however, the definition is limited so as to include only warm and hot springs, it will be noted that they are found in two positions that are characteristic, viz: 1st. In regions of great disturbance or dislocation, as along the base or in the midst of mountain ranges; and 2d, In areas of eruptive rocks, either where volcanic action is still going on or in regions where it has been long extinct.*

It should be mentioned here that dislocations and fractures determined by the elevation of mountains may be due primarily to the same causes that are active in producing at other places the eruptions of volcanoes. This subject will be referred to again under the heading of "The source of heat of thermal springs."

A few facts in relation to the position of warm and hot springs will now be briefly presented under the two heads just given.

First. *In connection with mountain corrugation.*—It is a well-known fact, pointed out by many writers, that warm and hot springs are apt to be found along the bases of mountain ranges, and usually near the line of junction of sedimentary rocks with the granitic nuclei, and the high temperatures are recognized as being due to the same causes that have elevated the ranges.

The lines of junction between the sedimentary and older rocks mark the points where the greatest number of fractures and fissures occur, by means of which the meteoric waters have access to and from the depths where they acquire their high temperatures.† Where two or three

*It is well to remember that it is a difficult matter to determine that volcanic activity is at an end even in regions that have been quiet during the historic period, inasmuch as our knowledge of the cycles of volcanic action is almost nothing, and cones thought to be extinct have frequently broken out in fresh eruption.

†In Sweden and Norway, springs that have temperatures of even a few degrees above the mean annual temperatures of their localities are rarely found. This is probably due to the fact that these countries are but little fractured, and yet they have been subjected to earthquake shocks.

axes of elevation cross each other the disturbance is greater and thermal springs ought to be abundant. This is the case at Ax in France, where three axes intersect. Leuk, in Switzerland, and Mont Blanc are other instances.

The baths of Mont Dore, in France, are situated near the geographical center of the hills at the point of greatest dislocation. In addition to this, however, the water escapes from columnar trachyte. Professor Rogers has pointed out the connection of the warm springs of Virginia with the anticlinal axes and faults of the Appalachian system. The thermal springs of Brazil are found in the coast ranges of mountains, and their relation to the hot springs in the Andes is analogous to that between the springs of the Appalachian region and those of the Pacific coast region in the United States.

In India many thermal springs owe their origin to their position in high mountain regions, especially in the case of the Himalayas. As we have already shown in Part II, flat, undisturbed regions such as the Mississippi Valley and great plains of North America, the table-lands of Brazil, and the steppes of Russia and Siberia are remarkable for the absence of thermal springs.

Second. *In areas of eruptive rocks.*—The connection of warm and hot springs with volcanic action is well established, and all works on geology treat of them under the head of igneous or volcanic phenomena. In Part II I have endeavored to show this connection, and a map of the warm and hot spring localities enumerated therein would be to a great extent identical with a map of the volcanic lines of the globe. The principal exceptions would be in the case of springs just noted as associated with mountain corrugation. In a few regions of volcanic rocks also, such as the Hebrides, there are no hot springs, and their absence can usually be explained by the fact that so long a time has elapsed that the rocks have lost their heat. The following facts are additional proofs of the connection of hot springs and volcanic manifestations.

Hot springs are formed during almost all eruptions of volcanoes,* especially if they are new, and the amount of volcanic activity is thought to be largely dependent upon the amount of water in their liquid contents.

Water in volcanoes is repeatedly noticed, and the "smoke," so called, which escapes is mostly steam. After violent eruptions steam usually escapes in such quantity that heavy rainfalls are caused. In Java and in South America, water, vapor, and mud are poured out by the volcanoes instead of lava. The water volcano of Gautemala is a veritable geyser on a grand scale. Indeed all writers on volcanoes recognize that the same causes which produce geysers are active in the production of volcanic eruptions.

As already noted, areas of hot and warm springs need not have *active* volcanoes in their vicinity, and two of the most noted geyser regions in the world, viz, New Zealand and the Yellowstone National Park, have been without any active manifestation during the historic period, and in both boiling springs are numerous. In Auvergne, in France, the eruptions date back to the Tertiary period, and in Nevada, which might fairly divide with California the claim of being the most active hot spring area of the United States outside of the National Park, the rocks are of Tertiary age, the latest of its rhyolites, according to King,† having been

* The noted eruption of Jorullo in Mexico, in 1759, caused the disappearance of two rivers, which were replaced by several warm springs. During the eruption of Monte Nuovo in Italy, in 1538, new hot springs broke out. Other examples will be given when the effect of earthquakes is considered.

† U. S. Geol. Expl. of 40th Parallel, Systematic Geology, Vol. I.

poured out in Pliocene time. On the island of Pantellaria hot vapors rise from the rocks, and yet there has been no eruption within historic time.

The presence of warm and hot springs is usually, and with apparent good reason, considered as an evidence of the waning of volcanic activity, and yet they may presage eruptions as in the case of Monte Nuovo, where hot water and steam escaped before the elevation of the mountain.

In Hungary, siliceous sinters and travertine have been formed previous to the pouring out of lava, and in Iceland the two are contemporaneous, many volcanic eruptions having occurred since the geysers first began to deposit their siliceous sinters. Still, in many places the only present sign of igneous activity is to be noted in the warm and hot springs, and they represent one of the last stages in the cycle of changes through which those portions of the globe subjected to volcanic action are destined to pass, and, eventually, even the springs will lose their heat.*

THE EFFECTS OF EARTHQUAKES.

The effect of earthquakes upon thermal springs is a proof of their intimate connection with volcanic action. In the first place, as we have already intimated, the existence of fissures and cracks in the earth's surface, by whatever means they have been formed, are efficient agents in causing hot springs by allowing meteoric waters to penetrate to great depths, and affording them afterwards free access to the surface. Earthquakes, as all know, occupy the very first place in the production of fractures of far-reaching extent, both geographically and geognostically.

The great Lisbon earthquake of 1755, which was so far-reaching in its effects that, according to Humboldt, an area equal to more than four times that of Europe was shaken by its vibrations, affected numerous springs in widely-separated areas. Those of Teplitz, in Germany, were muddy during the earthquake, then disappeared for a short time, and afterwards flowed more copiously than before. At Clifton, in England, the springs became turbid, and in France, at Luchon, the "*Source de la Reine*" was changed from a tepid spring to one having a temperature of 122° F., which has been retained.

An earthquake in 1638 caused the breaking out of the thermal springs of St. Eufemia, in Terra di Amato, and in 1783 (the year of the great Calabria earthquake) they became hotter and gave out a greater quantity of water. In 1660 an earthquake made some of the springs at Bagneres de Bigorre suddenly cold. In 1770 hot springs broke out on San Domingo during an earthquake, but they afterwards ceased to flow.

During the earthquake of 1766, at Cumana, in Venezuela, sulphur-water, with sand and mud, was frequently thrown from wells to a height of 30 feet.

In Iceland, before the eruption of Skapter Jokul in 1783, many springs were diminished, and in 1784, during an earthquake, according to Sir John

* The ruins of former hot springs localities are found in many parts of the Western United States, and I have described one in the report of the survey for 1871, page 192, and in the Yellowstone National Park individual springs die out. In Iceland, siliceous deposits are found where the springs are extinct, and according to Bischof (Treatise on Internal Heat of the Globe, p. 230), in the Sneefield Syssel in Iceland, a spring is found which is now cold, but once was hot, as its deposits show.

Stanley,* no less than thirty-five spouting springs made their appearance, many of which afterwards diminished in activity. After an earthquake in 1789 Old Strokhr, one of the geysers of Haukadal, gradually became a quiet spring, and the one *now* known as Strokhr began to erupt.†

Coming down to the nineteenth century we find that in Chili, after the earthquake of 1822, the hot springs of Cauquenes ceased flowing for a time, and after the earthquake of 1835 were temporarily lowered in temperature from 118° F. to 92° F.

The spring of Rita, in Ischia, increased in temperature during the earthquake of February 2, 1828, and the earthquake of 1837, in Syria, caused new hot springs to appear at Tabereah.

These are a few of the many instances that might be enumerated, but they are sufficient to prove that springs may either be brought into existence or may be destroyed by earthquakes, or made cold or hot, as the case may be.

According to Hoffman‡ numerous hot springs act as safety valves and serve as a protection from earthquakes, as at Sciacca, in Sicily, which is rarely disturbed by them, in comparison with other parts of the island.

In some cases the hot springs may become clogged or stopped up, and when the pent-up stream bursts out earthquake shocks may be caused. The shocks we experienced at Steamboat Point, on Yellowstone Lake, in 1871§ were probably due to inadequacy of the steam vents.

CHAPTER III.

CLASSIFICATION AND THERAPEUTICS.

Classification.—A few remarks upon the classification of thermal waters should perhaps be included here, although it is manifestly beyond our present scope to enter upon the subject in its completeness.

Thermal waters are subject to the same laws of classification as ordinary mineral waters, whether a chemical, therapeutical, geological, or geographical system be adopted. They may be alkaline, saline, sulphureted, carbonated, or chalybeate, according to their various ingredients which will usually be found present in less proportion than in ordinary mineral waters. There is, however, one exception—the proportion of silica is apt to be greater, especially if the springs have water at or near the boiling temperature. Of course, if the hot water does not have access, in the depths below the surface, to siliceous rocks, it may contain but a small percentage of silica.

As we shall have to do more with siliceous waters in the chapters upon the analyses, especially with those of the Yellowstone National Park, we shall refer to this subject of classification more particularly as it concerns the three great regions in which this class of thermal springs is found.

So few of the springs of the Yellowstone National Park have had

* Account of the Hot Springs of Iceland, p. 41.
† *Ibid.*, p. 32.
‡ Poggendorf's Annalen, V. XXIV., p. 70, cited by Bischof.
§ Report for 1871, p. 190.

their waters subjected to analysis that it is impossible to reduce them as yet to any systematic classification.* Before this can be done a large amount of chemical investigation will have to be made. The field has scarcely been entered upon as yet.

Krug Von Nidda, from his study of the Iceland springs, classifies thermal springs as follows:†

1. Those that are constantly boiling and bubbling up—permanent thermals.

2. Those in which ebullition only takes place at particular periods and which are perfectly tranquil in the interval—intermitting thermals.

3. Those whose surface is always undisturbed.

To the second class the geysers belong.

This classification is a natural one and comes to mind at once in a review of the features noted in our own region and in New Zealand. Still the difference between 1 and 2 is apparently only in degree, for if the springs (or at least many of them) noted in the catalogues of Part I of this report as constantly boiling are carefully watched, it will be noticed that there are periodical increases in activity, the ebullition becoming very violent at regular intervals, so that the springs might be called intermittent. Again, in many of the geysers of the Yellowstone Park, notably in the case of the "Union," in the Shoshone Basin, and the Giant and the Castle in the Upper Fire Hole Basin, there is constant ebullition in the intervals between eruptions. In the majority of the geysers, however, during the period of intermission, the water is perfectly tranquil. It is possible that many of the springs regarded as simply constantly boiling springs may be geysers, as in the case of the "Excelsior Geyser," which was not known as a geyser until 1881, although suspected in 1878 to be so by some members of the survey.

Still, the classification is a good one and corresponds in the main to that made naturally by the natives in both Iceland and New Zealand when they refer to the hot springs with which they are familiar. Although widely separated, not only geographically but in language, curi-

* Dr. Heizmann (in the Report of Reconnaissance of Northwest Wyoming, &c., by Capt. Wm. A. Jones, pp. 305 and 306) proposes the following general classification for the springs of the Park, which I give in tabulated form:

Class.	Localities in Yellowstone National Park.	Comparable to—
1. Neutral, and containing carbonic acid and sulphureted hydrogen.	Turbid Lake, east shore of Yellowstone Lake, 8 miles from Orange Creek.	Virginia White Sulphur Springs, Aix la Chapelle. As to chemical composition, to Meinberg (Lippe Detmold).
2. Acid and sulphureted hydrogen only.	Opposite head Yellowstone River; Cañon (falls), east side of river; Orange Creek Springs, 6 miles from Orange Creek.	Bareges, Cauterets, Bagnols (Lozère).
3. Iron marked	Pelican Creek, 6 miles from mouth.	To all sulphated chalybeate springs except in temperature.
4. Carbonic acid marked	Gardiner's River	To Carlsbad in thermality and effects; in constituents, to St. Galmier (Loire).
5. Carbonic acid and silica marked.	Geyser regions of Fire Hole River.	In constituents and effects, to Rockbridge Springs, Va.

† See Karsten's Archives, Vol. IX, p. 247; also Jameson's Philosophical Journal, Vol. XXII, pp. 90 and 220, and Bischof's Researches on Internal Heat of Globe, Vol. I, p. 226.

ously enough the same distinctions are made, as the following table shows:

Icelandic names.	New Zealand names.	Character of springs.
Hver	Puia	Boiling hot springs, including intermittent springs or fountains.
Nama	Uku Puia	Boiling mud-pools.
	Papa Puia	Boiling springs, with clear water and siliceous deposits.
Laug or Lauger	Waiariki	Quiet springs, suited to bathing.
	Ngawhas	Non-boiling springs, or solfataras.
Reykir		Springs that send up clouds of steam.

Hochstetter divides the New Zealand springs into two groups, as follows:*

1 Acid springs which have no periodical outbursts of water, and in which siliceous incrustations are either wanting or are inconsiderable in quantity.

2. Alkaline springs, which include geysers and are characterized by deposits in which silica, chloride of sodium, carbonates, and sulphates are the principal ingredients.

To these Doctor Hector† adds a third, in which the deposits are calcareous sulphates, and includes the springs of White Island, in the Bay of Plenty‡, in which the sea-water accounts for the difference in chemical composition. Hochstetter is of the opinion that the acid springs gradually become alkaline, and after building siliceous tubes become spouting springs or geysers. This subject we shall refer to again in a future chapter.

We have already said that, with the present incomplete knowledge of the chemical composition of the waters of the Yellowstone Park springs, it would be useless to reduce them to any systematic chemical classification. In fact it would be impossible to do so with any approach to accuracy. In the catalogues of Part I we have noted the springs as constantly boiling, quiet, or geyser-like, in accordance with Von Nidda's classification.

As to their chemical composition, the springs of the Park can be grouped under one of the following heads, in a rather broad classification, based upon the predominance of the principal ingredient, viz:

1. *Calcareous springs.*—As the Gardiner's River Springs and Soda Butte.

2. *Aluminous springs.*—Mud springs of Hayden's Valley, Yellowstone Lake, and the Fire Hole Basin.

3. *Siliceous springs.*—Including a majority of the springs of the Park.

This order we shall follow in the chemical chapters which we are well aware are very incomplete, especially when the vast number of springs within the limits of the Park is remembered.

*In his New Zealand, English Edition, p. 432.

†In New Zealand, Inst. Trans., III, 1870, p. 284.

‡ The mineral waters of New Zealand are classified as follows by Dr. Hector, director of the Geological Survey, the system being based upon the analyses made in the colonial laboratory.

Saline.—Containing chiefly chloride of sodium.

Alkaline.—Containing carbonates and bicarbonates of soda and potash.

Alkaline, siliceous.—Waters containing much silicic acid, but changing rapidly on exposure to the atmosphere and becoming alkaline.

Hepatic or sulphurous.—Waters, the prominent character of which is the presence of sulphureted hydrogen and sulphurous acid.

Acidic waters.—In which there is an excess of mineral acids, such as hydrochloric and sulphuric acid. (*Report on the mineral waters of New Zealand, by James Hector, M. D.; C. M. G., F. R. S., Director of the Geol. Survey in New Zealand thermal springs districts, &c., page* 25.)

THERAPEUTICS.

This is scarcely the place to consider the therapeutical value of thermal springs, but a few words may not be out of place, especially with reference to the Yellowstone National Park. The pages of ancient writers contain frequent mention of thermal springs. Temples were erected near them, and they were made the sites of medical schools, hospitals, baths, and resorts for the amusement of the sick. Their curative effects were widely celebrated.

The springs of Tiberias were used by the Romans, and, with those of Ischia, still maintain their reputation.

The most celebrated bathing-place of the Roman Empire was the hot sulphur springs of Baiæ, on the gulf of Naples.

In their conquest of Northern and Western Europe the Romans sought out the springs of the country, and in Acqui, Aix or Aachen, Dax, &c., the names of modern towns derived from the Latin *aqua*, we have testimony of their former celebrity as watering-places.

Pliny, in his Natural History (book xxxi, § 1), says, in speaking of water and springs, "They spring wholesome from the earth, on every side, and in a thousand lands; the cold, the hot, the hot and cold together, as at Tarbellum (Dax), in Aquitania, or on the Pyrenees, where they are separated only by a small interval, or get the warm and tepid, announcing relief to the sick, and flowing from the earth only for man, of all living things." Among the Romans warm bathing was indulged in to excess, and at one time there were eight hundred thermæ in the city of Rome. Many traces of the Roman baths remain. They were buildings of grandeur and magnificence, adorned with every architectural beauty, statuary, and mosaics. The baths of Diocletian and the baths of Caracalla were the most celebrated.

The reputation of thermal springs for medicinal and bathing purposes has descended to the present day, as the spas of Europe and our own watering places prove. In this practical age, however, we have shorn the springs of the superstitions of the ancients, and the busy habits of modern times do not admit of the time and elaborate preparation that was bestowed upon the bath in the luxurious days of Imperial Rome.

We no longer depend upon hearsay as to the reputation of springs in the cure of disease. The chemist analyzes the waters and classifies them according to their constituents. His system will not, however, always agree with the therapeutical classification, for two waters may be chemically alike and yet very unlike in their medicinal effects. There is something that seems to escape him.

In Europe both the chemical composition and therapeutical effects of the principal thermal springs have been carefully studied, and until the same is done with the springs of the Yellowstone National Park all that can be said upon the subject must of necessity be to a certain extent tentative. All the chemical analyses that have been made are but as a drop in a bucket of water.

In New Zealand, in the township of Rotorua, under "the thermal springs districts acts of 1881," a medical officer has been appointed in charge of the district and a hospital erected, where the waters will be used so as to enable patients to receive the full benefit of their advantages.

A laboratory also has been established for the purpose of facilitating a thorough analysis and study of the composition and therapeutic values of the various waters, so that by their use a definite line of treatment in different forms of disease may be arrived at.

When similar arrangements are made in the Yellowstone Park we will learn the values of the different waters. One thing is certain, we have there all the conditions necessary for baths of all kinds, and it is for bathing that thermal waters are mainly used. The range of temperature is all that is needed, and vapor baths can be extemporized almost anywhere.

A considerable portion of the benefit derived from a residence at certain watering places is doubtless due to various other hygienic conditions, such as altitude, change of scene or habits, &c. As a sanitarium the Yellowstone Park offers the most varied attractions, and now that railroad access to it is daily becoming easier, its value will be more highly appreciated.

When we were at Gardiner's River Springs in 1871 we found a number of persons, who were residents of Montana, using the waters (mainly for external use) with benefit. Chronic forms of rheumatism and some syphillitic diseases would doubtless be alleviated by the use of these waters. Dr. C. L. Heizmann has paid some attention to this subject and his classification of the Yellowstone springs has already been referred to. In his report to Captain Jones he says:

> Reference to the meteorological tables will explain the unfitness of this region, except for *non*-debilitating diseases, those of the cutaneous and lymphatic systems of the skin, scrofulous (but not tubercular) diseases, rheumatisms, and articular maladies. For asthmatic diseases, bronchial catarrhs, and some forms of dyspepsia; for phthisis, malarial sequalæ, &c., it is evidently inappropriate, and for an additional reason, that of the debilitating result of even a few days' inhalation of the sulphurous air about springs.*

CHAPTER IV.

COMPARISON OF GEYSER REGIONS.

It is of course difficult for one who has not seen each one of the three geyser regions (Iceland, New Zealand, and the Yellowstone National Park) to make anything like a complete comparison of their features, and certainly it is impossible to be dogmatic. Still, nature works according to laws that are the same in all parts of the globe, and a view of any one of the three regions will, to a great extent, help to explain phenomena observed in either or both of the others. The comparison can, perhaps, be more readily made when the American locality is the one actually observed, as the Iceland and New Zealand fields have been known for a long time, and have been more thoroughly studied and described than the Yellowstone Park. This is especially true of the geyser of Iceland, while our own geysers are only just beginning to be subjects of careful scientific investigation.

In the few following pages it is proposed to consider briefly the extent, resemblances, differences, and comparative age of the three regions already indicated.

Extent.—The three small maps incorporated in this report (pages 71, 304 and 313) present to the eye, probably in the best manner, a comparative view of the three great geyser regions. Expressed in figures the areas within which the springs are included are as follows:

	Square miles.
Iceland	5,000
New Zealand	2,500
Yellowstone National Park	3,578

*Reconnaissance of N. W. Wyoming, sc. p. 307.

In the Iceland region there are about six areas or groups, which are from 40 to 50 miles apart. In New Zealand there are about ten areas, the greatest distance between them being about 15 miles. In the Yellowstone National Park there are between thirty and forty areas, and if they are followed, starting with the Mammoth Hot Springs and going southward through the geyser basins of Fire Hole River to Shoshone Lake, Heart Lake, and back northward, via Yellowstone Lake and Yellowstone River, there will be only two points where the air-line distances between spring areas is as much as 16 miles.

In Iceland there are only three areas with geysers of note. In the Yellowstone National Park there are at least eight such localities, and in New Zealand fully as many. In the number of springs and noted geysers the two latter regions far exceed Iceland, in which "Geyser" and "Strokhr" are the two prominent spouters. For those in New Zealand the reader is referred to Chapter II, Part II, and to the recapitulation and the end of Part I for the geysers of the Park. As to the number of springs in New Zealand, an enumeration has probably never been made, but they appear to be very numerous, and are found on siliceous plateaus or mounds, as in our own region.

The following table gives the size of individual areas for comparison:

Locality.	Area in acres.	Number of springs and geysers.
Geyser area of Haukadal, Iceland	20	100
Geyser area of Rekium, Iceland	50	100
Whakaari Island, Bay of Plenty, New Zealand	30	.....
Siliceous plateau at Orakeikorako, New Zealand	1	76
East side of Rotomahana, including Te Tarata, New Zealand	6½	85
Upper Geyser Basin Fire Hole River, in Yellowstone National Park	2,560	440
Lower Geyser Basin Fire Hole River, in Yellowstone National Park	19,200	693
Mound of Castle, Yellowstone National Park	3½	15
Gibbon Geyser Basin, Yellowstone National Park	275	200 to 300
Giantess Group, Upper Fire Hole Geyser Basin	18	55
Grand Group, Upper Fire Hole Geyser Basin	30	70
Fountain Group, Lower Geyser Basin	15	17

Some of the individual groups in the geyser basins of the Yellowstone Park have been included in the table, so that a fair comparison with the Orakeikorako plateau can be made. We have no data as to the extent of the various New Zealand areas, but several of them include a number of siliceous plateaus upon which springs are found. Of course in each of the three countries there are hot springs outside of the limits of the maps as we have given them here, and if we take these into account, the American localities will exceed the others, especially if the Nevada and California springs are counted. If the springs of Snake River, south of the Park, and those of Shields River and the Musselshell, with others to the north (all of which are on the same north and south line as the geyser basins of Fire Hole River), are considered as a part of the same system as the springs of the National Park, the total length of the line is about 200 miles.

As to the heights to which the geysers throw their columns there is probably not much difference between the three regions, although the Yellowstone Park probably has a greater number of geysers which erupt regularly to 100 feet or more. The records of the New Zealand geysers are deficient in this respect.

The greatest height recorded as attained by the Great Geyser of Ice-

land is 360 feet, and in the National Park the Excelsior Geyser has spouted to a height of 300 feet. In New Zealand 200 feet is the highest column recorded.* There are many, however, that spout to the height of 100 feet. The bulk of water in the New Zealand geysers is usually much greater, which is probably the reason the columns, during eruption, do not attain greater heights. The Thibet geysers spout 50 feet, a height frequently noted in the regions just described.

Resemblances.—One of the first points to attract attention when the three maps already referred to are compared, is the presence in each of lakes. In Iceland there are six, in New Zealand fifteen, and in the Yellowstone National Park there are four of considerable size, besides a number of small and comparatively unimportant ones.

Lake Taupo, in New Zealand, is 25 miles long and 20 miles wide. Yellowstone Lake is 20 miles long by an average width of about 8 miles. In Iceland Hvitarvatn is nearly 10 miles by 18, and Thingvalla-vatn has a length of about 20 miles and a greatest width of 10 or 12 miles.

In the three regions hot springs seem to be associated with the lakes, and especially is this the case in New Zealand and in the Yellowstone National Park.† Although we have not considered the Thibet geysers in the comparisons we have made, it is interesting to note that they are found near the the Lake Tengri Nur.

In Part II, Chapter II (page 313), we noted the fact that the springs of New Zealand could be grouped in three parallel lines, the most eastern of which was the longest. In the Yellowstone National Park there appears to be a similar linear arrangement. The Mammoth Hot Springs, the Gibbon Geyser Basins, the geyser basins of Fire Hole River, and the Shoshone Geyser Basin are on the same north and south line in the western part of the Park. In the east, Brimstone Basin, the Pelican Creek Springs, and the springs of the East Fork appear to indicate a second line, while between the two are several scattered spring areas.

The extension of the western line northward and southward beyond the limits of the Park has already been indicated.

This linear arrangement appears to be analogous to the linear arrangement so frequently noted in the case of volcanoes.

Another point of resemblance between the three regions is in the character of the deposits, which are alike in appearance, structure, and chemical composition, with the exception of the minor constituents, as shown in the chapter giving the analyses. The character of the rocks is also similar, acidic volcanic rocks being predominant in each region. In Iceland rhyolite, phonolite, and palagonite are found in the vicinity of the geysers.

In New Zealand rhyolites and rhyolitic tuffs are the prevailing rocks. According to Hochstetter, the rocks of Lake Taupo are quartzose trachytic lavas.

A glance at Mr. Holmes' geological map of the Yellowstone National Park will show that rhyolites are the prevailing rocks. Mr. Holmes' report will present more detailed information in regard to them, and to it the reader is referred. New Zealand and Iceland are alike in being islands.

Differences.—In elevation above sea-level we find that the three regions under consideration are very different. The geyser of Haukadal

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*J. G. Corbett in Trans. New Zealand Institute.

† The geological map of Mr. Holmes indicates that there were formerly lakes of greater extent than exist at present, and that the geyser basins of Fire Hole River, or at least the lower one, are the sites of ancient lakes.

in Iceland is less than 500 feet. In New Zealand the elevations are from 1,000 to 1,300 feet, and in the Yellowstone National Park the range is from about 6,000 to 8,000 feet.*

The plateau upon which the Iceland geyser is situated is surrounded on three sides with glaciers. In New Zealand the atmosphere is humid and comparatively favorable to a growth of vegetation that is not found in either of the other regions.

The New Zealand springs are usually of greater size than those of either Iceland or the Yellowstone region. There is in neither of the latter a hot lake, like Rotomahana, which is a mile wide by a mile and a quarter in length, and has an average temperature of 78° F. The pool of Te Tarata measures 80 by 60 feet, and the pool of Otakapuarangi is about 50 feet in diameter. Although there are a number of cones or chimneys, the large basins seem to predominate. In the Yellowstone Park the springs are, as a rule, smaller, although the Grand Prismatic Spring in the Egeria, or midway basin, measures 250 by 350 feet, and the hot lake, near the Steady Geyser, in the Lower Fire Hole Basin, measures 750 feet by 1,000 feet. Still, the geysers usually have cones or chimneys, as in the case of the Union, Giant, Bee Hive, and others described in Part I, many of them being shown in the illustrations.

In Iceland the springs are also comparatively small, and there appear to be no chimney-like forms; the Great Geyser is situated on a rather gently-sloping mound, and the geysers at Reikium have no deposits or mounds. This brings me to the next subject, viz, the—

Comparative age of the three geyser regions.—It is difficult, and perhaps impossible, to say, with absolute certainty, which of the three regions possesses the greatest age. Still, there are a couple of reasons which appear to me to indicate that they stand in relation to each other as follows, beginning with the youngest, viz:

Iceland.
New Zealand.
Yellowstone National Park.

The *first* reason I shall give for this opinion is based upon a comparison of the volcanic condition of the three regions.

Iceland may be considered as still in a state of volcanic activity, although, perhaps, its fires are gradually becoming dormant. It has had eruptions as late as 1860 and 1875. There are twenty volcanoes on the island, and Hecla, which is nearest the geysers of Iceland, being distant only about 40 miles, has had twenty-two eruptions since 1004 or 1005, the date of the earliest record concerning it.

In New Zealand the volcanoes adjacent to the geyser areas have sunk into the solfataric stage, and the natives have no tradition of any eruptions.† In the Yellowstone National Park it cannot be positively determined where the ancient volcanoes stand.‡ It would seem, therefore, that Iceland is the youngest, and the Yellowstone Park the oldest, in its geyser development, if we consider the latter coincident with the later stages of volcanic action.

Secondly, when we compare the deposits of the geysers in the three regions we find that in the Yellowstone Park there is usually a chimney-

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*The Thibet region has probably an elevation of at least 15,000 feet, and is therefore the most elevated geyser region known.

†According to Dr. Hector the volcanic forces of the north island of New Zealand were active during the last Tertiary period, and are not yet altogether dormant.

‡Mr. James Eccles, in an article in the Quarterly Journal of Geol. Soc. of London, Vol, XXXVII, Aug., 1881, advances the opinion that Mount Washburn is an extinct crater, but in our opinion the evidence is somewhat obscure.

like cone surmounting a broader mound of deposit. In Iceland these chimneys appear to be absent, nor are they so prominent in New Zealand, the latter region appearing to be intermediate in this respect. Most of its geysers are described as pools of considerable size.

Prof. Joseph Le Conte, in his "Elements of Geology," page 104, says: "The more chimney-like form of the craters in the case of the Yellowstone geysers is probably due to the greater abundance of silica in solution." This is not the case, as a single glance at the table in chapter VII will show that the proportion of silica is usually less in the Yellowstone Region than in either of the others. The one exception opal spring has no cone or chimney. This fact also points in the direction of greater age for the Yellowstone geysers. I think the reason for the greater prevalence of the chimney-like form in the Yellowstone Region is satisfactorily explained on the ground of their greater age. We have no data for a comparison of the actual thickness of the sediments or depositions of the three regions, and if we had they might be to a certain extent misleading, as the rate of deposition must be variable. A great antiquity can certainly be accorded all three of the regions.

Section II.—PHYSICAL AND THERMAL CONDITIONS.

CHAPTER V.

FORMS OF BASINS, ORNAMENTATION, AND COLOR OF THE WATER.

FORMS OF BASINS AND ORNAMENTATION.

No matter where we find thermal springs we find that certain conditions are the same. Wherever calcareous springs are seen, the deposits assume certain forms, one of the most constant being that of the beautiful bath-like basins (Fig. 18) arranged in terraces so characteristic of the Mammoth Hot Springs of Gardiner's River. The same forms are seen at Hierapolis, in Asia Minor, and in fact wherever springs exist that contain a large percentage of calcium carbonate. It is not necessary that the water should be hot. In the cavern of Luray, in West Virginia, basins similar to those mentioned above are found. The same form of basin is also seen in siliceous springs, but they are not so marked, as the deposition of the siliceous sediments is not so rapid. The Te Tarata, in New Zealand, is the most marked instance of siliceous terraces. Many of the springs in the geyser basins of Fire Hole River show these terraces on a small scale. They are well marked on the slopes leading from the Old Faithful Geyser. This form of basin is characteristic of slopes over which the water flows from the main springs. The shapes and forms of the latter present an almost inconceivable variety in the various Geyser Basins of the Yellowstone Park. Perfect funnel shapes are seen, as in the Black Sand Geyser in the Upper Fire Hole Basin (see Plate XXVIII in Part I). Others are bowl-shaped, while still others are in the form of basins surmounting tubes. The plates in Part I will give the reader a clearer idea of the external forms and ornamentation of the springs than can be given in words. Some of these deep pools are beautiful beyond description. Filled with brilliantly clear water of sea-green turquoise and indigo-blue tints, the pure white siliceous basins are indescribably lovely. The corrugated sides of some break the light into its primary constituents and reflect veritable rainbows. Some of the

FIG. 17.—View of Oblong Geyser, Upper Fire Hole Basin, showing ornamentation of the edges or rim.

basins, as the Giantess in the Upper Fire Hole Basin, and the Union in the Shoshone Basin, are globular. Plans and sections of these geysers, with others, are shown in Figs. 23 to 27.

The geyser regions of Iceland and New Zealand have basins and pools similar to those of the Yellowstone Park. The ornamentation is alike in all regions where siliceous springs occur. The tendency is to a circular or oval form, and the character of the rim will depend upon the character of the spring. In a quiet pool the edge may consist of scalloped plate-like masses that extend inwards over the water like cakes of ice. A spring of this character is seen in the Rustic Group of the Heart Lake Basin (see Plate XLI*a*, Columbia Spring, in Part I). A very common form is that of globular masses of siliceous sinter, which may form the edge of the spring, as in the case of the Brown Sponge Spring in the Shoshone Geyser Basin, or be scattered over the bottoms of the pools or basins, as in the Turban and Grand Geyser in the Upper Fire Hole Geyser Basin.

Other springs, like the Deluge Geyser in the Heart Lake Basin, have edges or rims that look as though they had been cut out with a die. The coloring of these rims is almost as various as the springs themselves. One of the most peculiar is the Bronze Geyser, or spring, in the Shoshone Geyser Basin. The pool containing the water is of a golden yellow, approaching in places a saffron tinge. The rim, however, is a perfect imitation of bronze. The metallic luster is perfect.

In some springs, where iron is a prominent ingredient, the coloring of the deposits surrounding the basins is brilliant. The brightest of pink and rose tints are displayed, with reds and browns, upon a pure white ground. The Grand Prismatic Spring of the Egeria Group of the Lower Fire Hole Basin is one of the most brilliantly colored springs in the National Park. The reader is referred to Chapter VII, of Part I, for the description.

Among all our springs and geysers we have none that presents so simple a form as the Great Geyser of Iceland on so large a scale. It may be considered the typical form of a geyser having an almost perfect saucer-shaped basin, surmounting a tube remarkable for its great depth. Fig. 22 gives a section of this geyser. The sides, as shown in the diagram, are, perhaps, a little too regular, but it is very nearly a correct section, with the exception of a ledge on one side.

ON THE COLOR OF WATER.

One of the most interesting facts in connection with the springs of the Yellowstone National Park is the color of the water in many of its various springs. A glance through Part I of this report will show that the tints observed are usually shades or tints of blue, grading into greens, the latter becoming very brilliant where the water is contained in a basin that is lined with sulphur. The blues are very pure in most cases. That these colors are not peculiar to the springs of our noted geyser region will be rendered evident on a perusal of Part II of this report. Iceland, New Zealand, Java, and in fact every hot spring region can present its green or blue tinted springs.

Father Joseph de Acosta* writes:

> In New Spaine I have seen a spring, as it were, ink, somewhat *blew;* in Peru another, of color red, like bloud, whereupon they called it the red River.

* In the Natural and Moral History of the Indies, by Father Joseph de Acosta, London, 1604. Printed in London for the Hakluyt Society, 1881.

This blue color is not confined to springs, for many lakes, notably the Swiss lakes and Lake Tahoe of California, have it in perfection, and in the glaciers of the Alps* and in those of Norway it is seen. It is also noted in many rivers, the Rhone being one. The Rhine, at Geneva, is also blue.

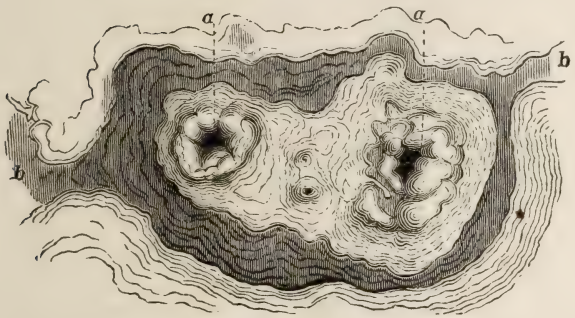
It is to be regretted that we could not bring in some specimens of the water from the springs of the National Park in which the blue color was most noticeable, but the bottles did not reach us soon enough. Those that were procured were, however, examined by Dr. Henry Leffmann and myself, and compared with other waters. These experiments I present here in tabular form.

Glass tubes, 5 feet long and a half inch in diameter, blackened on the outside and wrapped with heavy brown paper, were used. Over the ends the glass was corrected for greenness, and they were held against a surface of snow first and afterwards against white porcelain:

* Forbes (Travels through the Alps of Savoy, Edinburgh, 1843, page 71), speaks of blue caverns in the glaciers, and considers the color to be that of pure water.

Fig. 18.
Ornamented Basins at Mammoth Hot Springs of Gardiner's River.

FIG. 19.—Rim of a geyser in Upper Fire Hole Basin, Yellowstone National Park.



a a Cones. *b b* Outlets.

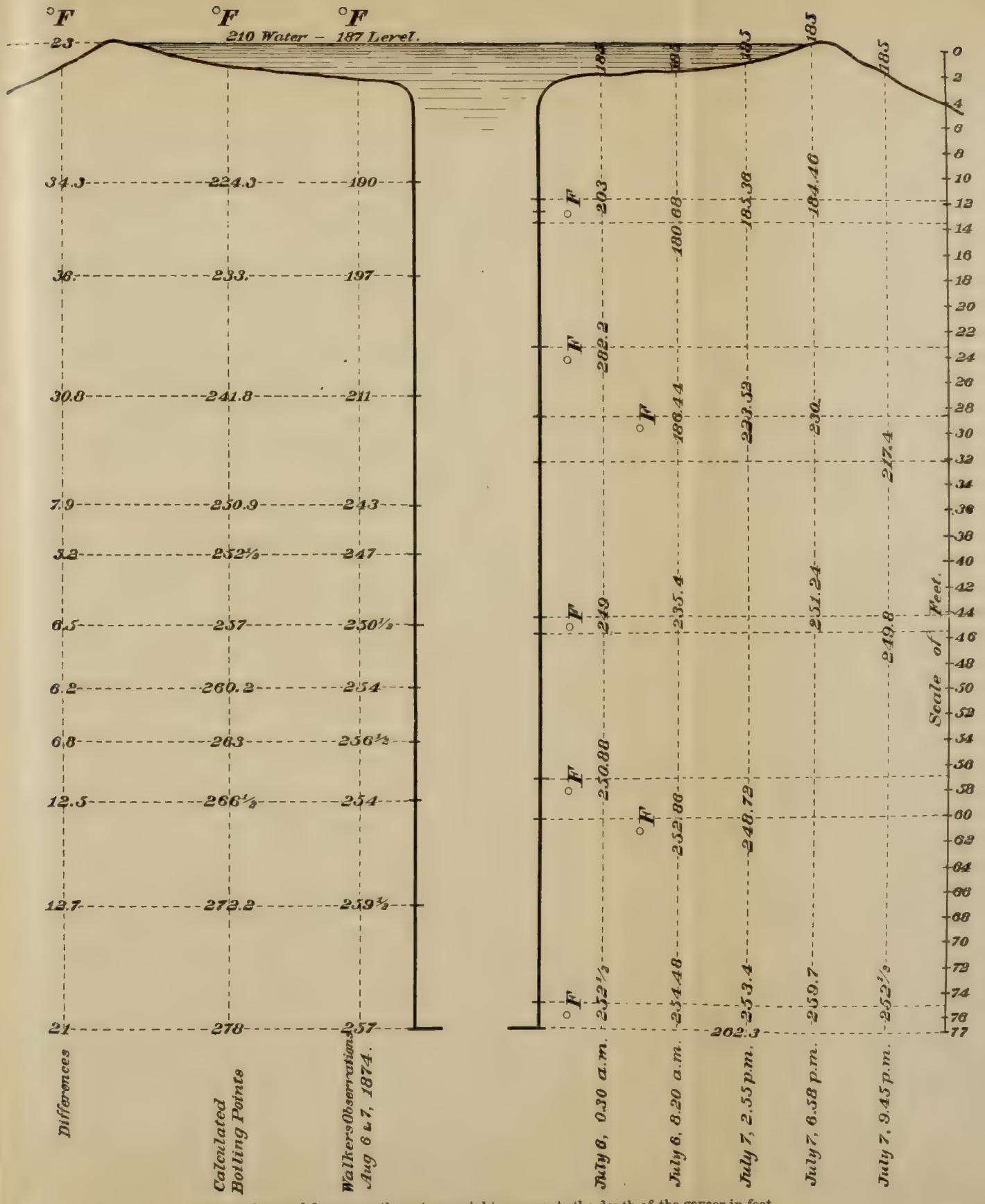
FIG. 20.—Plan of Grotto Geyser.

FIG. 21.—Globular masses in the crater of the Turban Geyser, Upper Fire Hole Basin.

1	Specimen.	Color when tube is held against snow or porcelain.	Color when sunlight is flashed through the tube.	Color when magnesium light is flashed through the tube.	Color at night with luminous flame of Bunsen burner.	Remarks.
1	Air alone	Colorless, except in shadow, when a very faint blue tinge shows.	Colorless			
2	Cleopatra Spring water, Mammoth Hot Springs, Yellowstone National Park.	Light blue	Almost colorless	Silvery gray	Yellowish blue	Cleopatra water contains over 98 grains of solid matter to the gallon.
3	Water from spring No. 17, on main terrace, Mammoth Hot Springs, Yellowstone National Park.	Grayish blue (Indigo blue) tint.				The solid contents in this water are over 76 grains to the gallon.
4	Water from Echinus Geyser, Gibbon Basin, Yellowstone National Park.	Grayish green				Solid contents over 52 grains to the gallon.
5	Water from Pearl Geyser, Gibbon Basin, Yellowstone National Park.	Grayish green				Solid contents over 72 grains to the gallon.
6	Water from Jug Spring, in Lower Geyser Basin of Fire Hole River, Yellowstone National Park.	Greenish				Solid contents over 98 grains to the gallon.
7	Distilled water	Light greenish	Slightly yellowish tinge in strong light.	Yellow green	Yellowish green	When compared with No. 1 is decidedly greenish.
8	Distilled water (boiled)	Light greenish		Brilliant yellow		
9	Distilled water (filtered)	Yellowish green				
10	Snow water (melted snow)	Light greenish				
11	Schuylkill River water (from hydrant in Philadelphia).	Muddy yellow		Reddish yellow	Yellow	
12	Schuylkill River water (same as 11, settled).	Yellow				This color is more decided yellow than the color of flor. sulph. with which it is compared.
13	Schuylkill River water (boiled)	Yellow, slightly orange yellow, not very clear.				
14	Schuylkill River water (boiled, cooled, and settled over night).	Yellow, but somewhat opaque.				
15	Schuylkill River water (filtered)	Yellow, clearer than No. 14.				
16	Schuylkill River water (settled with a few drops of ammonia).	Yellow, somewhat greenish, compared with No. 14.				
17	Alcohol	Clear, light, greenish yellow.				
18	Schuylkill River water (settled after standing 2 weeks).	Greenish yellow, like No. 17.				This contained 7 grains mineral ingredients to imperial gallon.

1	Specimen.	Color when tube is held against snow or porcelain.	Color when sunlight is flashed through the tube.	Color when magnesium light is flashed through the tube.	Color at night with luminous flame of Bunsen burner.	Remarks.
19	Philadelphia well water	Light greenish yellow.				
20	Water from Opal Spring in Gibbon Geyser Basin, Yellowstone National Park.	Orange yellow				This water by reflected light is bluish opalescent.
21	Rosin in alcohol precipitated in distilled water.	Orange yellow (exactly like color of No. 20).		Ruddy orange		This specimen by reflected light was a perfect imitation of No. 20; a weaker solution gave a yellow color by transmitted light.
22	Bryn Mawr well water	Orange		Rich orange		This water is rich in organic matter, and contains but little mineral matter.
23	Hydrant water from Williamsport, Pa. (comes from mountain springs).	Yellowish green				This water contains between 5 and 6 grains of residue to the gallon.
24	Spring water from Forest City, Ark.	Grayish blue (somewhat like No. 3).				This water contains 20 grains to the gallon.
25	Solution of sulphate of quinia	Yellow, much like No. 12.				
26	Saturated solution of common salt (in snow water).	Yellow, with a slight greenish tinge.				

A number of chemical solutions were examined, but are not detailed in the table. A large number of experiments were made at different times; but, as a great many were merely repetitions, they are not enumerated.



The column of figures on the extreme right represents the depth of the geyser in feet.

FIG. 22.—Diagram showing section of Great Geyser of Iceland and temperature measurements. The temperatures on the right (July 6 and 7, 1846) are those taken by Bunsen and Descloizeaux.

These experiments render evident several facts:

First. The color in the specimens is independent of the chemical composition of the waters.

Second. It is not dependent upon the quantity of solid ingredients combined in them.*

Third. The color depends upon the mechanical state of the water, the blues showing when the water is most free from foreign particles, and as they increase passing from blue to green, yellow, and red.

It is probable that the chemical ingredients of the geyser waters are so perfectly dissolved that there is very little matter in a state of suspension, and thus it is that we have such bright coloring in so many of the Yellowstone, Iceland, and other springs.

We had reached this point in our investigations when we found that the whole subject of the color of water had been fully discussed by various writers. The best *resumé* of the subject probably is found in an article by Prof. John Le Conte in the San Francisco Mining and Scientific Press.† Forbes also gives some interesting information on the subject in Edinburgh Transactions for 1840. Other authorities will be cited in the Bibliographical Appendix. We can give here only the briefest sort of a synopsis.

It was very early recognized that the color of the sky and the color of pure waters were analogous, and that blue tints were due to reflection, and red ones to transmission of light.

Leonardo da Vinci (in *Traité de la Peinture*) ascribes the blueness of the atmosphere to the effect upon the eye of looking into infinity of space. Euler, in 1762, thought it probable that all particles of air possess a faint bluish tinge, so faint as to be imperceptible unless in a prodigious mass, while Muncke declared the whole thing to be an optical delusion, purely subjective. (See Gehler's Worterbuch, article "Atmosphere.")

Newton (Optics, Book II) says:

> The blue of the first order, though very faint and little, may possibly be the color of some substances; and particularly the azure color of the skies seems to be of this order, for all vapors when they begin to condense and coalesce in small parcels become first of the bigness whereby such must be reflected, before they can form clouds of other colors. And so, this being the first color of the finest and most transparent skies, in which vapors are not arrived to that grossness requisite to reflect other colors—as we find by experience.‡

Tyndall has investigated this subject practically and demonstrated that "sky-blue may be produced by exceedingly minute particles of any kind of matter."§

Sir Isaac Newton, Mariotte, Euler, Sir Humphrey Davy, Count de Maistre, Arago, and others, all thought the azure tints of the deep water of certain lakes and seas was due to the selective reflection of blue rays from the molecules of the liquid itself; while the green and other tints exhibited by other waters were thought to be the result of impurities or

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*Another proof of this fact is found in the analyses made by the Society of Public Analysts of England (see the Analyst, of London, vol. vi, February to December, 1881). In the tables they give the observations on the colors of the waters they have analyzed, and yellow waters are frequently noted as containing only 5 to 7 grains of solid constituents, and waters that are colorless, greenish, or blue, frequently have 35 grains of residue to the gallon. Some waters, also, that are green or blue at certain seasons become yellow or brownish at others, probably on account of their sources becoming turbid from rain.

†Physical Studies of Lake Tahoe; Colors of Sky and Water. San Francisco Mining and Scientific Press, January 1, 1881, to February 12, 1881.

‡Clausius, of Bonn, thinks the particles should have a vesicular structure, and says blue skies must have finely divided vapor. Pog. Ann., lxxvi.

§On Chemical Rays and the Structure of the Light of the Sky, in Fragments of Science, p. 258.

due to various modifications and admixtures of reflected light from suspended materials and from the bottom. Le Conte says:

> The scattering of the light is not molecular, but is evidently due to the presence of finely divided matter in a state of suspension, whereby the shorter rays of the beam are intercepted and diffused more copiously than the larger ones, thus rendering the trace of the light visible in the liquid and imparting a blue tint to the laterally scattered polarized light. The conclusion seems, therefore, to be inevitable that if water were perfectly free from all foreign materials, either in solution or chemical suspension—both chemically and optically pure—it would have no color at all by diffusion of light; in fact, inasmuch as no scattered light would be emitted from the traversing beam it would show the darkness of true transparency.

He thinks, therefore, that *pure* water has no color by diffusive reflection.

Some of the Welsh tarns or lakes, said to be bottomless, have an inky hue, and, according to Tyndall,* in some places in the sea the water, when looked down upon, was almost inky black, qualified by traces of indigo; and under the moraines of the Swiss Alps, where the ice is exceptionally compact and there is no scattering of light, the perfectly clear ice presents pitchy blackness.

Bunsen was probably the first one to make direct experiments upon the color of water.† He experimented with a 2-inch tube 2 yards long blackened with lampblack and wax to within an inch of the end, and held against white porcelain illuminated by a white light. He says, "Chemically pure water is not colorless, but has a pure bluish tint, which is visible only when a stratum of considerable depth is penetrated by the light." The smallest quantity of foreign matter disguises or alters the color. He considers that the greenish tint in the Swiss lakes is due to the color of the bottom.

Tyndall, in 1857, confirmed Bunsen's results. He used a tin tube 15 feet long and 3 inches in diameter, and stopped both ends. This tube was half filled, so that there was a column of air as well as of water. A white paper was placed a short distance from the tube upon which the color was displayed. Blue-green was the purest color he got. By the passage of an electric beam through distilled water he obtained a blue-green image. He says:

> Water absorbs all the extra red rays of the sun, and if the layer be thick enough it invades the red rays themselves. Thus, the greater the distance the solar beams travel through pure water the more they are deprived of those components which lie at the red end of the spectrum. The consequence is that the light finally transmitted by water, and which gives it its color, is blue.

In December, 1861, W. Beetz, of Erlangen, obtained results similar to those of Bunsen and Tyndall.‡ Le Conte used three glass tubes 3 centimeters in diameter, and connected them by rubber tubing, getting an aggregate length of 5 meters. He used solar light thrown into a darkened chamber by a porte-lumière. He also passed it through a secondary screen, rendering it uniform in size, so that he got an approximate mathematical beam, and secured its transmission along the axis without danger of mixing with reflected light from the tube. Distilled water gave him a greenish-blue or yellowish-green tint. Pacific Ocean water gave green to yellowish-orange color, and the same tints were found in the purest hydrant water. He says:

> Hence it appears that, in a general way, my experiments confirm the opinion that pure water absorbs to a somewhat greater extent the solar rays constituting the red end of the spectrum.

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*Hours of Exercise in the Alps. Voyage to Algeria to observe the Eclipse. Am. ed. N. Y., 1871., pp. 463–470.

†Edinburgh Philosophical Journal, vol. xlvii, 1849, pp. 95–98. Also, Ann. der Chem. and Pharm., vol. lxii, pp. 44, 45, 1847.

‡Philosophical Magazine, 4th series, vol. xxiv, pp. 218–224, September, 1862. Also Pogg. Ann., vol. cxv, pp. 137–147, January, 1862.

Herr Boas, of Kiel, experimented with a zinc tube 46 feet long, the ends being closed with glass plates. Distilled water gave a fine deep blue-green color; the red end was absent, and the yellow feeble, and the maximum brightness in the green. Water of the Kiel supply let no light through the length stated (46 feet); with half the length it appeared deep orange, blue and green failing entirely. He also performed quantitative experiments.

In his quantitative experiments the author illuminated two screens from the same light-source (sodium light or a gas flame), before which was placed red glass, or sulphate of copper solution. The light from one screen went through water in a tube; that from the other along the tube outside.

Both beams were brought into a position for comparison by means of total reflection prisms; the screens were shifted till equal brightness was reached, and from their position the coefficients of absorption could be approximately inferred. The decrease of absorption towards the blue in the case of distilled water is thus clearly shown.*

He also found that the light issuing from the water was weakly polarized in a plane passing through the sun and the direction of the beam. As to fluorescence his experiments had a negative result.

Soret, in a letter to Professor Tyndall, from Geneva, March, 1869, maintains that the blue color of Lake Geneva is due to the suspended solid particles, from the fact that he established by direct experiment that this light presents phenomena of polarization identical with those of the light of the sky.† His experiments were confirmed by experiments on the water of Lake Lucerne made by Prof. E. Hagenbach.

In a very interesting article in the Philosophical Magazine‡ Mr. E. L. Nichols argues that the effect of the light on the nerve termini in the eye must be taken into account. These are variously affected by the different colors and have their own laws. For feeble rays violet nerves are very sensitive, and as the intensity increases these become tired or dazzled and are incapable of receiving their full share of effect. For rays of dazzling intensity the red nerves are in the most sensitive condition, while those affected by the more refrangible components of the ray are comparatively dull. Of simple colors, as the brightness of the ray increases, red and green change to yellow, and blue becomes white. Passing cloud-shadows show that what under shadow is indigo blue in direct sunlight becomes silver gray. He says the difference between moonlight and sunlight is only in intensity, but the yellow impression of sunlight gives place to a bluish one. A ray that is white in ordinary light becomes blue as it gets faint. Rays less refrangible than blue are absorbed in the passage of light.

In our experiments detailed in the first part of this chapter we noticed that when a bright ray of sunlight was passed through the tube in the case of distilled water the greenish light acquired a yellowish tinge. The blue light of Cleopatra water became colorless or white, and the column of air when in shadow acquired a bluish tinge. On one occasion night came on while we were examining a specimen of Schuylkill River water, and as the light faded the beam transmitted through the tube became orange and finally quite ruddy. This is in accordance with the facts just presented.

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*Nature, 1881.

†Philosophical Magazine, 4th series, vol. 57, p. 345, May, 1869; Compt. Rendus, tome 68, p. 911, April, 1869; Archives des Sci. Phys. et Nat., tome 35, p. 64, May, 1869.

‡A New Explanation of the Color of the Sky, by E. L. Nichols; Philosoph. Mag., 5th series, vol. 8, No. 51, p. 425–433, 1879.

CHAPTER VI.

TEMPERATURE.

SOURCE OF HEAT.

In a preceding chapter we have noted that the waters of thermal springs, and in fact of all springs, are meteoric in their origin, and we now inquire whence is their heat derived. In the Greek Authology, in a poem on the Pythian hot baths by Paulus Silentiarius, chief silence-keeper to the Emperor Justinian, is the following speculation as to the cause of the heat of springs:

> It is conceived by some that there are narrow fissures below the earth; that opposing currents meeting from various quarters are compressed, and by that compression acquire no ordinary heat. Others, on the contrary, say that in recesses of the earth there are somewhere sulphurous ores; that the neighboring stream, therefore, meeting with a violent heat, from the inability to remain below, rushes upward in a mass. Which opinion will my readers adopt? The former? I do not myself embrace this. I agree with the latter, for there is a mephitic offensive stench clearly proving it. * * * 'Twas thus the hot, bubbling fluid issued for the benefit of mankind—an inanimate Hippocrates, a Galen untaught by art.

This was written, in all probability, some time about 550 A. D.

As long ago as the third century the question was answered by St. Patricus, who was probably bishop of Pertusa, as follows:

> Fire is nourished in the clouds and in the interior of the earth, as Etna and other mountains near Naples may teach you. The subterranean waters rise as if through siphons. The cause of hot springs is this: waters which are more remote from the subterranean fires are colder, while those which rise nearer the fire are heated by it, and bring with them to the surface, which we inhabit, an insupportable degree of heat.*

These quotations present three of the theories as to the heat of the earth—viz, chemical, mechanical, and volcanic agency. The following are the sources of the earth's heat: 1st. The sun; 2d. Chemical and mechanical action; 3d. Internal heat. As sources of heat for thermal springs, only the second and third need to be mentioned here.

2d. *Chemical and mechanical action.*—The amount of heat received by the earth through chemical action is inconsiderable, and the theory that the heat of thermal springs is due to chemical action, although it once had many advocates, was demolished by Bischof. In limited areas a part of the heat may be due to chemical action. Mechanical action, however, as in the motion attending the plicating and uplifting of rocks, has been demonstrated by Mallet, Hunt, Le Conte, and others, to be a very efficient source of heat. Professor Rogers, Mr. G. K. Gilbert†, and others have pointed out the coincidence between the occurrence of thermal springs and mountain corrugation in the United States. In the east we have the Appalachian region, in which we find a system of thermal springs, in which, however, the temperatures do not exceed 108°. In Arkansas, the Ozark ridges account for the presence of the springs, and in the West we have the Rocky Mountain corrugations. Along the Atlantic coast, in the Mississsippi Valley, and in the Colorado Plateau we have no hot springs.

That the temperatures in the mountain regions are not due alone to the regular downward increase in temperature is probable, because, in the case of the artesian well at Louisville, Kentucky, the water from the bottom of the well has a temperature of 86½°, while at the surface it is only 76½, and in the Virginia region the surface temperature reaches

* Humboldt's Cosmos, Bohn's edition, vol. 1, p. 221.

† Report upon Geological and Geographical Explorations and Surveys West of the 100th Meridian, &c., vol. iii, pages 145–149.

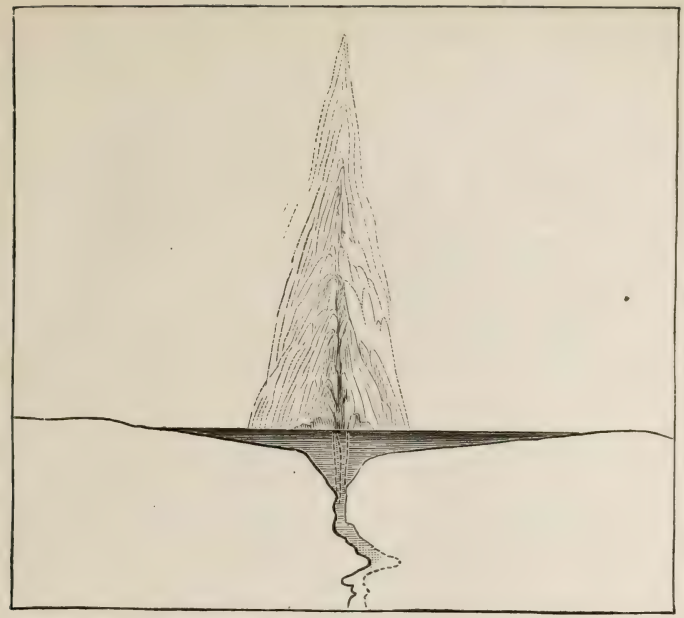

FIG. 23.—Section of Saw Mill Geyser, Upper Fire Hole Basin, Yellowstone National Park.

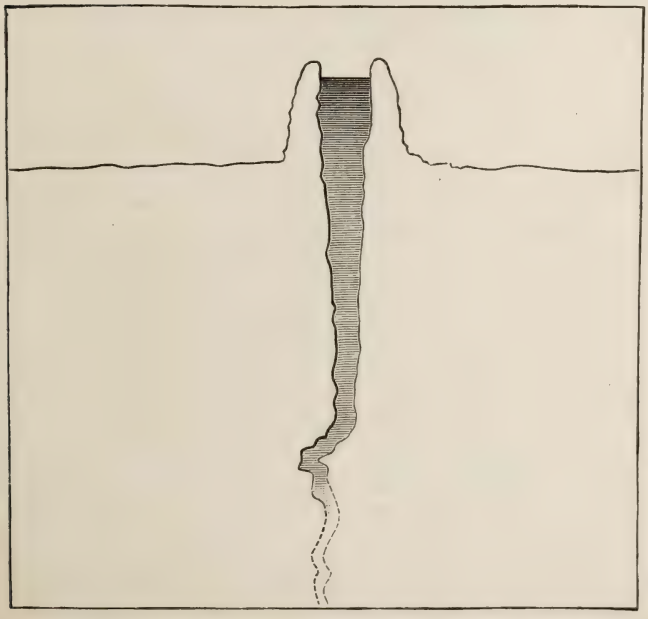

FIG. 24.—Section of Bee Hive Geyser, Upper Fire Hole Basin, Yellowstone National Park.

110° F. The plication and folding in the rocks of the Appalachians not only afford the opportunity for the water to escape, but as the result of that motion have imparted to the rocks an increased temperature which is seen in the waters of its thermal springs.

3d. *Internal heat.*—The proofs of the internal heat of the earth, given in Dana's Manual of Geology, are briefly as follows: 1st. The spheroidal form of the earth; 2d. The increase in temperature, as shown in artesian wells and shafts in mines; 3d. The wide distribution of volcanoes over the globe. The increase of temperature in the earth was noted in 1664 by Kircher.* Boerhäve† also, in 1732, mentions the increase of heat toward the center of the earth, and Mairan,‡ in 1719, advanced the theory of the existence of fire in the interior of the earth.

Ever since the middle of the eighteenth century observations have been taken in mines and springs§ in France, Germany, England, and America, so that the average rate of increase is pretty well known.

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* Mundus Subterraneus, 1664, fol., vol. ii, pp. 184 and 185, cited by Bischof.

† Elementa Chemiæ, Lipsiæ, 1732, vol. i, p 403, cited by Bischof

‡ Mém. de l'Académie, pour 1719, cited by Bischof.

§ The following table gives the results of borings for artesian wells, which Arago long ago declared were peculiarly adapted to the determination of the increase of temperature below the surface of the earth.

Locality.	Depth of well.	Temperature at the bottom.
EUROPE.		
	Feet.	° *F.*
Pregny, near Geneva	680	63.
Tottenham Court road, England	1,001	57.
Rank Herlany, in Hungary	1,457	75.
Kissingen, Germany	1,878½	66.
Passy, in France	1,923	82.
Grenelle, near Paris, France	2,000	85.
Neusalzwerk, near Minden, Prussia	2,200	91.
Mondorf, in Luxembourg	2,278	89.
Buda Pesth, in Hungary	3,160	178.
UNITED STATES.		
Charleston, South Carolina	1,250	87.
Louisville, Kentucky	2,086	86.¼
Belcher well, at Saint Louis, Mo	2,199	73.4
Columbus, Ohio	2,775½	91.
Insane asylum, Saint Louis, Mo	3,843½	105.

The following table presents some of the temperatures that have been observed in mines:

Mines.	Depth.	Temperature.	Authority.
	Feet.	° *F.*	
Bex	677	63.05	De Saussure in Annal. de Chem. et Phys., vol. liii, p. 245.
Killingworth coal mine	1,200	77	Earth and Sea. By W. H. Davenport; Adams, London, 1870.
Dolcoath copper mine	1,377	75½	Do.
Guanaxuato, Mexico	1,607	98.15	Humboldt in Gilbert's Annalen, vol. lxxvi, p. 450.
Maria mine, near Aachen	1,844	75.56	Proc. Inst., Civ. Engineer's, vol. lii p. 397.
Comstock mine	2,000	130	J. A. Church, Amer. Jour. Sci. and Arts; April, 1879, p. 289–296.

A comparison of these tables shows a fair agreement between the mines and artesian wells, except in the case of the mines at Guanaxuato and the Comstock mine of Nevada. The explanation is probably to be found in the presence of igneous rocks at both localities.

The average increase, as given by various authorities, is shown in the following table:

Rate of increase.	Authority, &c.
1° F. for 50 or 60 feet	Dana's Manual of Geology, p. 699.
1° F. for 53 feet (1° in 30 to 1° in 90)	Elements of Geology. Le Conte.
1° F. for 27 feet	This is at Yakupk, Siberia, found by Magnus (quoted by Dana).
1° F. for 45 feet	M. Cordiér quoted by Lyell, in Principles of Geology, p. 539.
1° F. for 24 feet	At Monte Masse, in Tuscany. (Judd's Volcanoes, p. 341.)
1° F. for 51½ feet	Professor Everett, from Observations on the Sperenberg Boring (depth of 3,390 feet.)
1° F. for 66 feet	H. B. Medlicott (Observations on Underground Temperature. Rec. Geol. Surv, of India, vol. x, pp. 45–48) deduces this from temperatures at 350 feet depth in coal field of Sarepla.
1° F. for 23 feet	At Budy Pesth. (Judd's Volcanoes, p. 342.)
1° F. for 62 feet	Report of the British Association for the Advancement of Science, 1881.
1° F. for 68 feet	Report of the British Association for the Advancement of Science, for 1879.

The rate of increase does not follow the same law in all parts of the earth. Some writers think it increases to a certain depth and then begins to decrease again. Everywhere, however, that observations have been made there appears to be an increase as we descend towards the center of the earth. In this increase of heat, of course, we have sufficient reason for the heat of springs coming from a great depth. In many thermal springs, however, as in our Yellowstone region, this regular increase in temperature is not sufficient to account for the high temperatures, and we must look for the cause, in plications, and faults, or in the volcanic rocks in which the springs are located. The intimate connection of hot springs and volcanic action has long since been noted. In Part II we have traced this connection around the globe and found it existing in every land. No *boiling* springs exist in other than volcanic regions—*i. e.*, where there are volcanic rocks. The rocks need not be geologically recent, for in the Yellowstone National Park they are, in part at least, Tertiary in age, and yet we have some of the hottest temperatures known anywhere. In Iceland and in New Zealand we still have active volcanic action in adjacent regions, and are not, therefore, surprised at the high temperatures. On the other hand, where we have modern volcanic action we may not have very high temperatures (due perhaps to the springs not coming from so great a depth as in other cases). Thus, the hottest spring in Europe, which is connected with volcanic action, according to Professor Forbes,* is at the baths of Nero, near Naples, where the temperature is 182°.2 F. In Iceland, in New Zealand, and in the Yellowstone National Park, temperatures above the boiling point have been obtained.

The hottest spring in Europe outside of the area of modern volcanic activity, according to M. Arago, is that of Chaudesaigues in Auvergne,† with a temperature of 176 °F. That the mere presence of volcanic rocks, whether ancient or modern, is not sufficient to produce hot springs is well shown in our Rocky Mountain region, for we have large areas, notably in Southern Arizona and California, Washington and Idaho Territories, and in Oregon, where there are no hot springs. Perhaps the explanation may be found in the fact that the rocks are mainly flows, and the mass has so cooled that any thermal springs formerly existing have become extinct. In many portions of the West the remains of

* Phil. Trans., t. ii, p. 603, for 1826.
† Annuaire du Bureau des Longitudes, 1836.

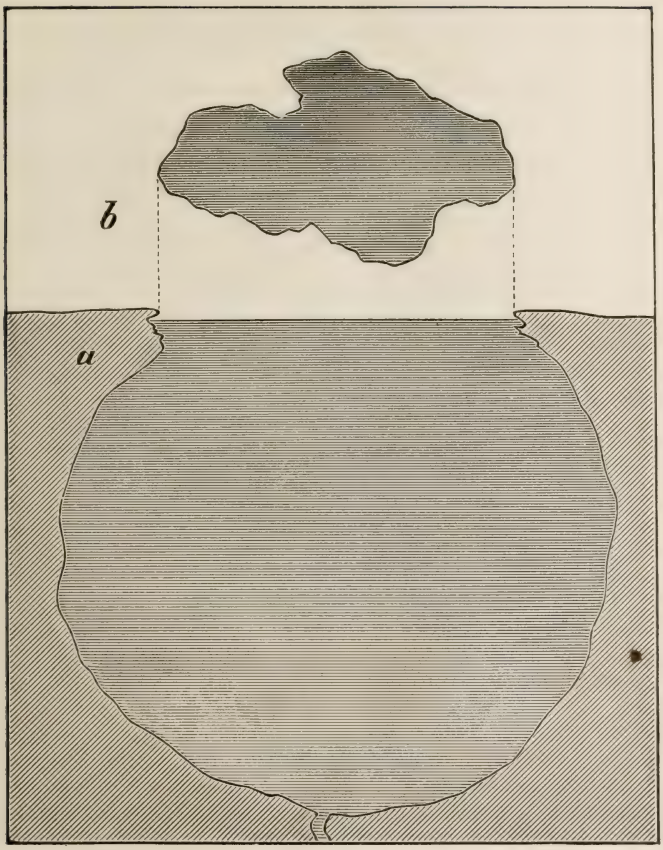

FIG. 25.—Plan and section of Giantess Geyser, Upper Fire Hole Basin, Yellowstone National Park.

hot springs are found on a large scale. Many of the flows are more modern than the rocks of the Park, but in the course of time they have become cooled. It is scarcely to be doubted that the springs at Bear River, in Idaho, were once hot, and one still retains a temperature of 88° F., while others range from 50° F. to 85° F.* It is well known that in the neighborhood of volcanoes that have become extinct, a rapid decrease of temperature may frequently be noted. Between the visits of Humboldt and Burkart, a period of 24 years, the temperature of the springs on Jorullo, in Mexico, decreased 40½°.†

In the Yellowstone National Park, therefore, we must have an enormous thickness of trachytes or rhyolitic rocks, if they are simply flows, or the springs must occupy the lines of fissures that exist in bodies of volcanic rock extending to great depths.

The influence of eruptive or volcanic rocks upon the temperature of water is well shown in the Comstock mines, which are the hottest in the world. Prof. John A. Church, in an article in the American Journal of Sciences and Arts, April, 1879, pp. 288–296, details his observations on the underground temperatures of the Comstock Lode in 1877. He finds that in the lower levels (1,900 to 2,000 feet) there is a pretty uniform temperature of 130° F. The water which filled the Savage and Hale and Norcross mines for two years, gave a temperature of 154° F. In another place it had a temperature of 157° F. Places of exceptionally high temperature were found in narrow belts in the rock. He says, "It is noticeable that the neighborhood of a dike is apt to be hotter than other portions of the rock."

Prof. J. P. Lesley, in Nature, June 19, 1879 (vol. xx, pp. 168, 169), says that Professor Barker told him that on a visit to the Comstock mines, he found no uniform temperature, but remarkable differences, so that he came to two conclusions—viz: 1st. That the heat was a hot-water heat; and 2d. That the hot waters were heated mechanically by those continuous movements of the country so plainly shown in the mines and at the surface. Professor Lesley asks:

> Has any one, in the discussion of Mallet's hypothesis, thought of bringing its probability to such a test as the volatilization of the hydrocarbons of coal beds in a highly plicated region like Belgium? * * *
>
> It is a remarkable fact, and one which seems to me inconsistent with the mechanical theory of earth heat, that of two extensive regions, Belgium and Eastern Pennsylvania, equally and excessively disturbed by plications, all of the coal beds of the one are anthracite, and all of the others are bituminous.

He also compares two undisturbed regions, Western Pennsylvania and Arkansas, which have their coal beds horizontal, and yet one is bituminous and the other anthracite. His idea is that, if movements of the strata produce all the needful heat, no plicated coal beds should escape being converted into anthracite.

Church, referring to Barker's idea, does not agree with him that the heat is a hot-water heat, nor that it is due to mechanical action. He says:‡

> The hot spots are evidently narrow and long, and as the mine openings sometimes intersect and sometimes follow them for some distance, a given level will be for a part of its length in a hot belt, and for a part in the general mass of heated rock, or one level may be in a hot belt and show a much higher temperature than the level below, which entirely escapes the exceptionally hot ground.

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* Report U. S. Geol. Survey of Terr., for 1878, pp. 594, 595.

† Phyiscal, Chemical, and Geological Researches on the Internal Heat of the Globe. By Gustave Bischof, p. 225.

‡ Nature, vol. xx, p. 503.

It appears from this that even in volcanic rocks, where the temperature is greater than in other places, there are variations.

From what has been written in the preceding pages the following conclusions may be drawn as to the source of heat in thermal springs:

1st. According to the ideas uniformly received at the present time the heat of thermal springs is due to the internal heat of the earth, which meteoric waters acquire by penetrating the rocks, after which they come to the surface as thermal springs.

2d. Ordinarily this heat is simply due to the regular downward increase of heat in the earth (about 1° to 50 or 60 feet), the temperature being higher or lower according to the depth penetrated.

3d. In regions of mountain corrugation thermal springs are more numerous and of higher temperatures than in undisturbed regions, probably because the mechanical movement attending plication increases the amount of heat, and the fractures caused allow the water to penetrate to greater depths.

4th. Thermal springs occur pre-eminently in regions of eruptive rocks, whether recent or ancient, and no boiling springs are found outside of volcanic areas, proving that in such areas the downward increase of heat in the rocks is greater. The heat increases with the depth usually, and yet may also be, to a certain extent, independent of the depth.

CHANGES OF TEMPERATURE.

From the fact that the existence of the hot-spring region of the Yellowstone National Park is a recent discovery, no data of value can be presented bearing upon the question of change in the temperature of its hot springs. Temperatures have only been recorded for a few years, and no changes outside of those due to the personal errors of observers or differences in the thermometers used can reasonably be looked for.* Lava and scoria are bad conductors of heat, and where there is a considerable thickness of rock the heat in the lower portions may be retained for ages. It is possible to walk over lava which is red hot a very short distance below the surface, and which will ignite sticks thrust into cracks in it. The non-conducting quality of lava as to heat is strikingly shown in its preservation of ice in Italy and other places. On Etna, in 1828, a great mass of ice was found under a covering of lava which was the cause of its preservation.† The city of Catania draws its supply of ice from this source. Hot vapors emerge from between masses of ice and the crater of Etna.

During the eruption of Vesuvius in 1872 masses of snow were covered with a thick layer of scoria, and afterwards by a stream of lava, and three years later it was found consolidated into ice, but not melted.‡ Deception Island, in the South Shetland Islands, is composed of alternate layers of ice and ashes.§

We can therefore readily conceive how heat may be retained in volcanic rocks, especially when they reach to immense depths, although active volcanic manifestations may have ceased to show themselves for long periods. It is probable, therefore, that if we had a record of temperatures of springs of the Yellowstone Park, extending back for a long time, little change would be noticed.

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*The comparison of temperatures taken in 1871 with those of 1878 will be found in the various chapters of Part I of this report.

†Lyell's Geology, page 412.

‡Judd's Volcanoes, page 110.

§Lyell, p. 412.

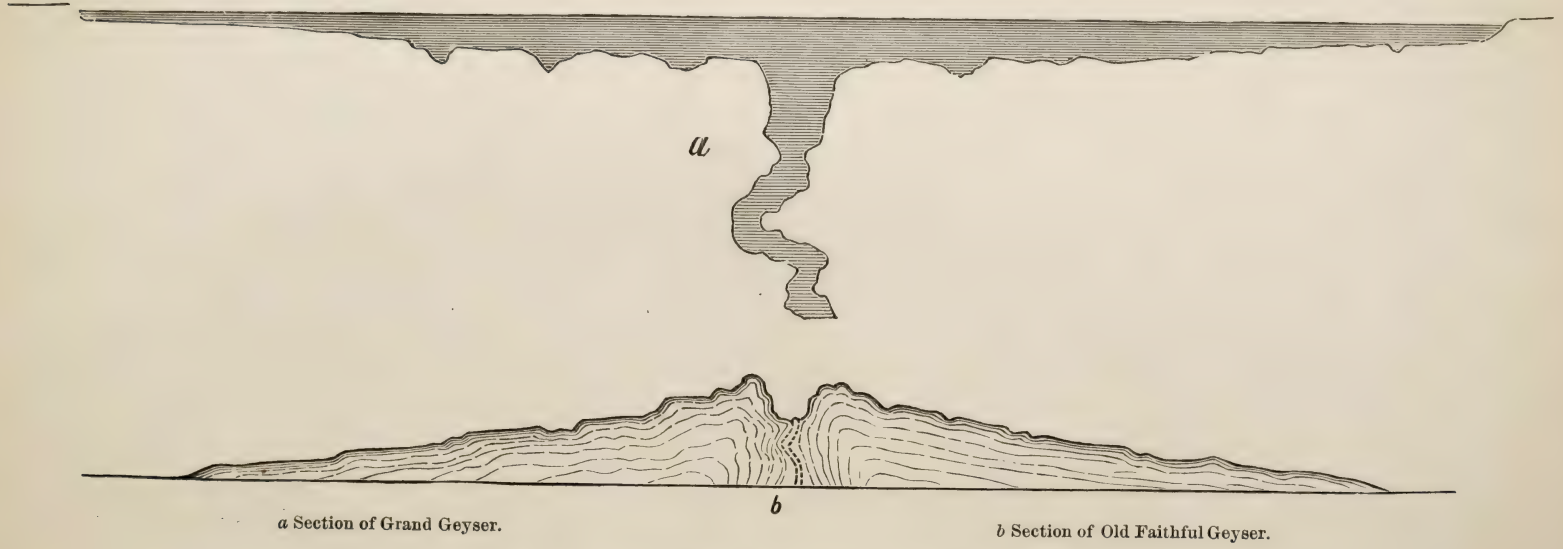


FIG. 26.—Geyser sections, Yellowstone National Park.

In the following tables the observations upon a number of springs are compared:

Steamboat Spring, on Bear River, at Soda Springs, Idaho Territory.

Year of observation.	Observer.	Temperature of spring.	Temperature of the air.
		°F.	°F.
1843	Frémont	87	28½
1871	Peale	85½*	
1877	Peale	87¾ and 88	80 and 79

*The thermometer used was a very ordinary one, and the low temperature may be due to its incorrectness, as the readings in 1877 were more than 2 degrees higher.

La Reine, at Bagnères-de-Luchon, in France.

Year of observation.	Name of observer.	Temperature of spring.
		°F.
1761	Camperdon	124.2
1818	Barran	119.7
1832	Boisigrand	122.8
1833	do	122.8
1835	Forbes	110.6
	*Filhol	131

*This observation is taken from Walton, p. 355, and the date is not given. The rest of the table is from Forbes's Philosophical Transactions, 1836, Part II, p. 571.

Tambour, or Le Grand Bain, at Barèges, France.

Year of observation.	Name of observer.	Temperature of spring.
		°F.
1739	Meighan	111.25
1750	Secondal	111–112
1826	Arago	111.4
1835	Forbes	111.9

This table and the following one are from Forbes (Philosophical Transactions, 1836, Part II, p. 571):

Locality.	Spring.	Carrere, 1754.	Anglade, 1819.
		°R.	°R.
Nyer		18	18.5
Vinca	Source de Nora	19.4	18.8
Molitz	Grande Source	30.3	30.3
La Preste	Grande Source	35.2	35.2
Escaldes	Source du Milieu	35.2	34
Vernet	Source Extérieur	43	42.8
Vernet	Source du Milieu	45.5	44.5
Arles	Escaldadon Gros	49	49
Thuez	Olette	60 (167°F.)	60

At Chaudes-aigues, according to Le Coq, the spring of Par in 1771 had a temperature of 167° F., and in 1828 it was 177½° F., seeming to have become hotter. The effects of earthquakes and active volcanic action upon the temperatures of hot springs have already been considered. Changes are frequently noted in regions that are actively volcanic.

COMPARISON OF SURFACE AND DEEP TEMPERATURES.

The tables in Part I give the deep temperatures of the Yellowstone springs whenever they were taken. In all the active springs an increase of temperature was observed. None of the springs are well adapted for obtaining deep temperatures, as the tubes soon become irregular and winding. The deepest temperature obtained was in the Bee Hive at a depth of 15 feet, which is small when compared with the Great Geyser of Iceland, where temperatures have been taken at a depth of 77 feet from the top of the basin. The Bee Hive would be one of the best geysers in the Park upon which to make comparative temperature observations. We had more time, however, at the Union Geyser. In this, as in all the geysers noted, there is a gradual increase in the surface temperature as the time for an eruption approaches.

In the case of the Union the increase was from 196° F. to 200° F. The deep temperature also increased gradually until, at 6 feet, a temperature of 208° F. was attained, which remained constant for a couple of days before the eruption. The gradual increase in temperature as the time of an eruption approaches was noted also in the Great Geyser of Iceland, by Bunsen and Descloizeaux. The following table will show this. The temperatures were taken at about 44 feet. (See diagram, Fig. 22.)

Date.	Time.	Time in relation to the eruptions.	Temperature.	Curve as plotted on diagram, Fig. 31.
	h. m.		° F.	
July 6, 1846	8 20 a. m.	3 hours after and 9 hours before	235.4	c, e.
July 6, 1846	0 03 a. m.	11 hours before	249	c, m, d.
July 7, 1846	9 45 p. m.	2 hours after	249.8	c, s, d.
July 7, 1846	6 58 p. m.	10 minutes before	251.24	c, g.

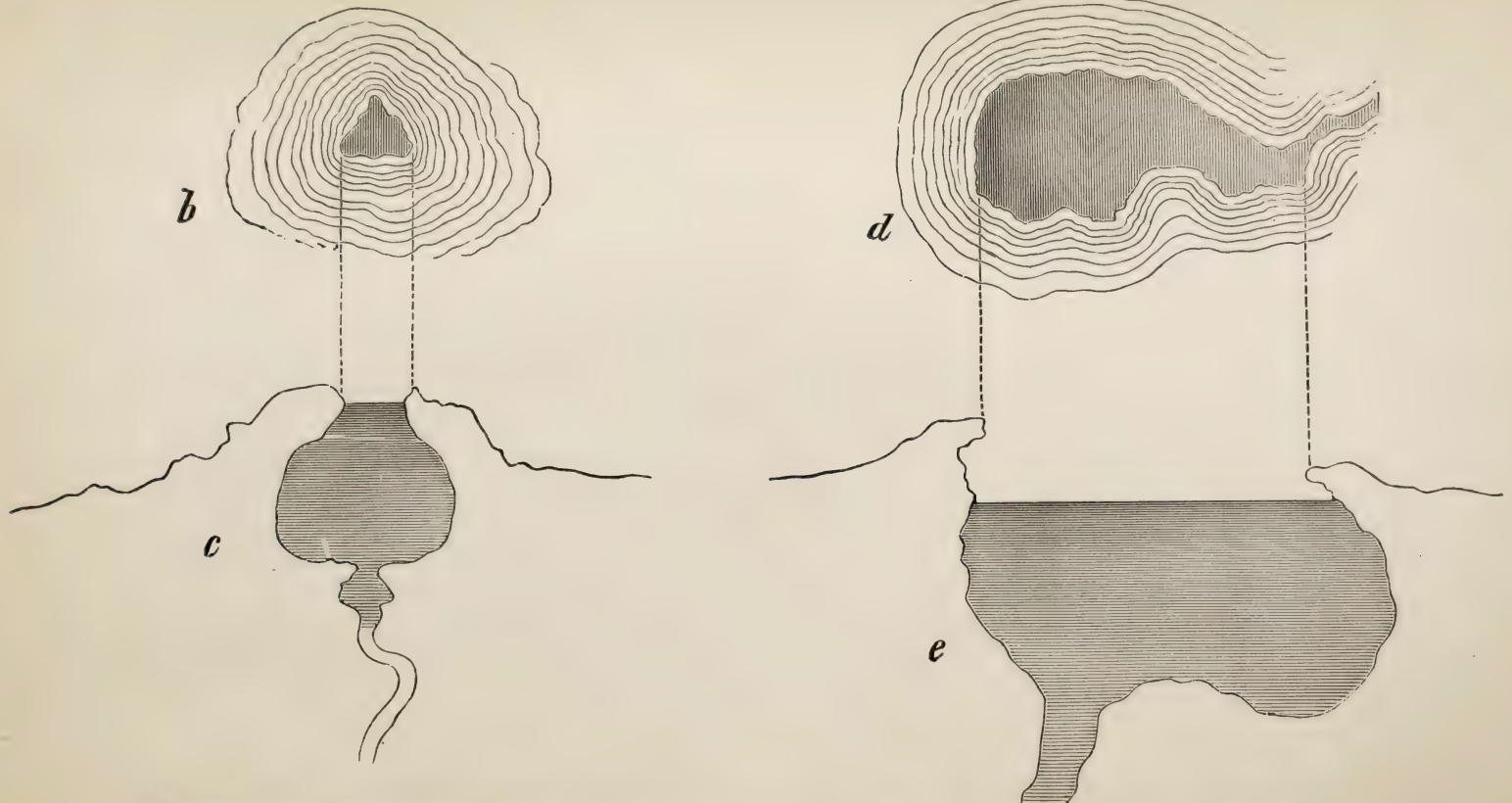
The calculated boiling point at this depth is 257° F.

This increase of temperature will be referred to again in a succeeding chapter, when we come to speak of the theory of the geyser.

In the table we give now are the surface temperatures before and at the time of action of some of the geysers of the Yellowstone National Park.

Name of geyser.	Location.	Temperature in the interval.	Temperature at or near time of eruption.
		° F.	° F.
Saw Mill	Upper Fire-Hole Basin	176	185
Tardy	do	163	169
Three Crater	do	156	169
Union	Shoshone Basin	196	208+
Little Bulger	do	165	185
Little Giant	do	192	200+

There are several interesting questions in regard to the question of temperature that present themselves, but we have not the space to take them up here. One, however, we must mention, and that is in regard to the boiling point being exceeded in some of the springs. The ex-



b Plan of center cone, Union Geyser. *c* Section of center cone, Union Geyser. *d* Plan of Trinity Geyser. *e* Section of Trinity Geyser.

FIG. 27.—Geyser sections, Yellowstone National Park.

periments of M. Donney are interesting in this connection. His results are as follows:*

1st. The constancy of the boiling point of water depends on its containing air in considerable quantity.

2d. There is a marked difference between the boiling point of water with air and water without air.

3d. A small quantity of air dissolved in water is sufficient to attenuate greatly the cohesion existing between the molecules of the water.

4th. Water freed from air as far as possible has its cohesion so increased that a higher temperature is necessary to evaporate it, and the boiling point is raised.

M. Donney raised water to 275° F. When water so heated does boil the production of vapor is instantaneous.

The water of geysers and hot springs has been boiled and reboiled for an inconceivable period, and is freed from air as no other water is. In addition, also, the irregularity of the channels offers obstruction to the free escape of the steam and it becomes superheated. In many springs, however, the surface does not boil, and yet far down in the tube ebullition and the formation of steam do occur, as the throbbings evince. As the bubbles of steam come towards the surface they meet with colder water and condense. In this way the water at the surface gradually becomes hotter and hotter. Spring No. 41 in the Giantess Group in the Upper Fire Hole Basin shows this condensing action. Large bubbles come in at the bottom of the funnel-shaped basin, but soon disappear, drawing a current of water towards the orifice, and the next moment it is repelled by the succeeding bubble.

CHAPTER VII.

CHEMISTRY OF THERMAL WATERS.

By A. C. Peale, M. D., and Henry Leffmann, M. D.

ANALYSES OF WATERS.

In this chapter we shall have reference mainly to the analyses of waters from the Yellowstone National Park.

When speaking of the classification of the springs on a preceding page we mentioned the fact that they differ from ordinary mineral springs only in the smaller proportion of ingredients and in usually having a larger amount of silica. We shall therefore consider the analyses with primary reference to the proportion of silica, especially in comparing them with analyses of other waters, with the single exception of the Gardiner's River Springs, where the calcareous element predominates.

None of the muddy waters have as yet been analyzed, but the character of the deposits warrants us in saying that they differ from the others principally in the amount of iron oxide and alumina contained.

The analyses of waters from the springs of Yellowstone National Park presented here are, we believe, the first approaching completeness that have ever been made. Unfortunately the bottles for securing the specimens reached us in the field after many of the most interesting springs had been passed. For this reason we have no specimens from the Upper

*In vol. 17, Memoirs of Royal Academy of Sciences and Belles-lettres, Brussels.

Fire Hole Basin, the Shoshone Basin, nor the Heart Lake Basin, and the only specimen from the Lower Fire Hole Basin is from the "Jug Spring" in the Thud Group. To obtain this we sent back a distance of at least 35 miles. All of the bottles were taken to and from the Park on mule-back until the terminus of the stage line was reached, and we think it remarkable that only one of the nine should have been lost through breakage. The capacity of the bottles is about half of an imperial gallon (about 5 U. S. pints, or a little over 2 litres).

We shall now take up the analyses in the order indicated in the chapter on classification, premising that we have no analyses of aluminous springs to present, and therefore only calcareous or calcic and siliceous springs will be represented, and of the latter only a few of the many that are found within the limits of the Yellowstone National Park.

CALCAREOUS OR CALCIC WATERS.

The only waters in the park in which the calcareous element is prominent are those of the Mammoth Hot Springs of Gardiner's River. The "Soda Butte," on the east fork of the Yellowstone, appears to have the same composition as the deposits of the Mammoth Springs, but its spring has been long extinct.

Calcium sulphate is found in some of the springs of the Gibbon Geyser Basin and in Jug Spring, in the Lower Fire-Hole Basin, but in both these basins the deposits are siliceous.

Specimens of water were taken from Spring No. 1, No. 2 (Cleopatra), and No. 17 (on the main terrace), at the Mammoth Hot Springs. That from Spring No. 1 was lost by the breaking of the bottle, and we had but one specimen in this case, and two from each of the other springs.

Cleopatra Spring (No. 2).—This spring is fully described in Part I, Chapter I. It will suffice to say here that the spring is a beautiful white basin, with a faint yellowish-red tint on the outer edge, and the water is of a sky-blue color. The specimens were collected September 17, 1878, and when the bottles were opened, in 1881, a slight deposit of amorphous carbonates was found. The water was strongly alkaline, and had a temperature of 154° F.

The following is the analysis:*

	Grams to litre.	Grains to imperial gallon.
Sulphuric acid	0.480	33.600
Silica	0.050	3.500
Chlorine	0.117	8.190
Calcium	0.200	14.000
Magnesium	0.0303	2.121
Sodium	0.240	16.800
	1.1173	78.211

Arranging this we have—

	Grains to imperial gallon.
Sodium chloride	13.496
Sodium sulphate	35.504
Calcium sulphate	13.587
Calcium carbonate	24.850
Magnesium carbonate	7.455
Silica	3.500
	98.392

*All the original analyses in this chapter are by Dr. Henry Leffmann.

Spring No. 17.—This spring is situated on the main terrace at the Mammoth Hot Springs. It measures 15 by 20 feet, and its white marble-like basin was filled with water of a temperature of 165° F., which had a light blue color.

Sulphuretted hydrogen gas appears to escape from the spring constantly.

When the bottle was opened a deposit of calcium carbonate was noticed, and under the microscope was seen to consist of crystals of calcite, of the form known as dog-tooth-spar.

The water was alkaline.

The following is the analysis:

	Grams to litre.	Grains to imperial gallon.
Sulphuric acid	0.332	23.240
Chlorine	0.164	11.480
Calcium	0.102	7.140
Magnesium	0.009	.630
Sodium	0.263	18.410
Silica	0.048	3.360
	0.918	64.260

This may be arranged as follows:

	Grains to imperial gallon.
Sodium sulphate	34.370
Sodium chloride	18.900
Calcium carbonate	17.920
Magnesium carbonate	2.170
Silica	3.360
	76.720

In the following table these analyses are compared with others in which similar constituents are found.

Spring.	Location.	Country.	Analyst.	NaCl.	KCl.	$MgCl_2$.	$CaCO_3$.	$MgCO_3$.
Cleopatra	Mammoth Hot Springs, Yellowstone Park.	United States	Leffmann	13.49	.....	.....	24.85	7.45
No. 17	Do	do	do	18.90	.....	.....	17.92	8.68
Hot Springs	Hierapolis	Asia Minor	J. L. Smith.	.....	.....	*1.40	95.76	2.87
Ladies' Boiler Bath, Hot Springs.	Arkansas	United States	Larkin	.0095	.....	.....	4.756	.153
La Reine	Bath County, Virginia	do	.....	.144	1.918	.....	20.789	3.212
	Bagnères de Bigorre	France	Ganderax and Rosière	4.343	.....	9.10	18.622	3.078
	Gastein	Austria	Wolf	3.452	.....	.....	3.452	.191
	Hammam-Meschouten	Algiers	Braun	29.092	1.287	5.505 *.759	15.800	2.965

Spring.	Location.	Country.	Analyst.	Na_2CO_3.	$MnCO_3$.	$FeCO_3$.	Na_2SO_4.	$CaSO_4$.
Cleopatra	Mammoth Hot Springs, Yellowstone Park.	United States	Leffmann	.....	.....	.....	35.51	13.59
No. 17	Do	do	do	.....	.....	.....	34.44	.....
Hot Springs	Hierapolis	Asia Minor	J. L. Smith	5.46	.....	.....	23.87	8.33
Ladies' Boiler Bath, Hot Springs.	Arkansas	United States	Larkin	.....	.....	.....	.451	.134
La Reine	Bath County, Virginia	do	.....	.....	.....	.134	1.228	2.082
	Bagnères de Bigorre	France	Ganderax and Rosière	.....	.....	5.60	†27.722	117.60
	Gastein	Austria	Wolf	.384	.191	.479	14.479	.....
	Hammam-Meschouten	Algiers	Braun	.....	.....	.....	1.157	26.660

Spring.	Location.	Country.	Analyst.	K_2SO_4.	$MgSO_4$.	Na_2HPO_4.	SiO_2.	Ca_3SiO_4.
Cleopatra	Mammoth Hot Springs, Yellowstone Park.	United States	Leffmann	.....	.....	.....	3.50	.....
No. 17	Do	do	do	.....	.....	.....	3.36	.....
Hot Springs	Hierapolis	Asia Minor	J. L. Smith	.....	30.17	‡.84	.56	.....
Ladies' Boiler Bath, Hot Springs.	Arkansas	United States	Larkin	.278	.....	.....	2.234	.556
La Reine	Bath County, Virginia	do	.....	1.61	6.779	.....	2.09	.....
	Bagnères de Bigorre	France	Ganderax and Rosière	.....	.....	.....	2.522	.....
	Gastein	Austria	Wolf	.096	.....	.384	2.301	.....
	Hammam-Meschouten	Algiers	Braun	.....	.471	.....	4.905	.....

Spring.	Location.	Country.	Analyst.	Al_2O_3.	Fe_2O_3.	Organic matter.	Loss.	Totals.
Cleopatra	Mammoth Hot Springs, Yellowstone Park.	United States	Leffmann	.....	.....	.....	.....	98.39
No. 17	Do	do	do	.....	.....	.....	.....	83.30
Hot Springs	Hierapolis	Asia Minor	J. L. Smith	.....	.....	.....	.....	.....
Ladies' Boiler Bath, Hot Springs.	Arkansas	United States	Larkin	.537	.125	.844	.....	§10.08
La Reine	Bath County, Virginia	do	.....	.....	.....	.....	.....	39.986
	Bagnères de Bigorre	France	Ganderax and Rosière	.....	.....	.479	3.778	192.84
	Gastein	Austria	Wolf	.....	.....	.....	traces.	‖25.41
	Hammam-Meschouten	Algiers	Braun	.....	.....	.42	.....	.....

* Calcium chloride. ‡ Calcium phosphate. § Contains traces of iodine and bromine.
† Including magnesium sulphate. ‖ Has traces of calcium, fluoride, and strontia.

SILICEOUS WATERS.

Siliceous waters predominate in the springs of the Yellowstone National Park, and we regret that more analyses cannot be presented here. Those given are with one exception from the Gibbon Geyser Basin, the most recently discovered of all the geysers basin of the Park.

FIRE HOLE GEYSER BASINS.

No specimens of water were obtained from the Upper Fire Hole Basin. In 1871 a small quantity of water was obtained from the Grand Geyser, and gave a result of $835\frac{25}{85}$ milligrams of solid matter to the liter, consisting mainly of silica, with lime, magnesia, chlorine, sulphuric acid, and a trace of iron.* The quantity was to small to determine these

* This analysis is mentioned on page 187 of report for 1871, but not credited to the Grand Geyser, as it should be.

constituents quantitatively. In 1873 Surgeon Heizmann determined that the water of "Old Faithful" contains ".14 grams of silica to the litre, with lime, a very small quantity of iron, alumina, and magnesia, carbonates, sulphides, chlorides."*

The water of another spring (not quantitatively analyzed), at the lower end of the Upper Fire Hole Basin he found, contained alumina, iron, magnesia, carbonates, chlorides, and sulphides, but no lime.

In the Lower Fire Hole Basin one specimen was secured, viz, from the "Jug Spring" in the Thud Group.

Jug Spring.—This spring (No. 8 in the Thud Group on the map of the Lower Geyser Basin) is 4 by 5 feet, and has a temperature of 190° F. The water is clear, and has an alkaline reaction.

The analysis gives the following:

	Grams to litre.	Grains to imperial gallon.
Sulphuric acid	0.020	1.400
Chlorine	0.274	19.180
Silica	0.208	14.560
Calcium	Traces.	Traces.
Sodium	0.492	34.440
	0.994	69.580

The probable composition of this water is as follows:

	Grains to imperial gallon.
Calcium sulphate	2.030
Sodium chloride	31.570
Sodium carbonate	50.750
Silica	14.560
	98.910

GIBBON GEYSER BASIN.

The Gibbon Geyser Basin is the one most recently discovered within the limits of the Yellowstone Park, Col. P. W. Norris, superintendent of the Park, having given the first description of it. The chart of its springs given in Chapter VI, Part I, is the first ever plotted, and the analyses here presented the first that have been made. The complete description will be found in Part I.

Echinus Geyser (No. 45 on the chart) is 40 feet in diameter, surrounded with blue, gray, and reddish border, forming a thin coating on the rocks, which are plainly visible, not being concealed by the deposits, probably because of the comparatively recent age of the spring. Below the spring are maroonred terraces of minute size. The water is greenish in tint, has a temperature of 180° F., is acid in reaction, and gives the following analysis:

	Grams to litre.	Grains to imperial gallon.
Sulphuric acid	0.112	7.840
Chlorine	0.118	8.260
Silica	0.280	19.600
Sodium	0.206	14.420
Calcium, Magnesium	Traces.	Traces.
	0.716	50.120

* Jones Report, N. W. Wyoming, p. 303.

The following arrangement will give its probable composition. The slight excess of sodium over that required to combine with the sulphuric acid and chlorine is put in the form of sodium orthosilicate ($Na_4 Si O_4$.). There are also traces of magnesium and calcium.

	Grains to imperial gallon.
Sodium chloride	13.650
Sodium sulphate	11.592
Sodium orthosilicate	10.584
Silica	16.191
	52.017

Pearl Geyser (No 68 on chart).—This supposed geyser is about 500 yards west of Echinus Geyser, in a wide flat space. It has a basin of about twenty-five feet diameter, in which the bluish-tinted water had a temperature of 162° when at a low point. The water fluctuates and bulges at intervals. It is alkaline and chemical examination reveals the following constituents:

	Grams to liter.	Grains to imperial gallon.
Sulphuric acid	0.0328	2.296
Chlorine	0.532	37.240
Silica	0.112	7.840
Calcium	0.006	0.420
Sodium	0.349	27.580
	1.0318	75.376

Arranging this, we get for probable composition

	Grains to imperial gallon.
Calcium sulphate	1.400
Sodium sulphate	1.890
Sodium chloride	61.390
Silica	7.840
	72.520

which is little more than a solution of common salt and silica.

The bottle when opened was found to contain about two tablespoonfuls of a deposit of the consistence of soft-boiled egg, consisting largely of silica. Under the microscope it was seen to be structureless, and when heated upon platinum became a clear opaline-tinted mass.

Opal Spring (No. 24 on chart, page 132).—This spring, which has the comparatively low temperature of 90° F., is some distance north of Echinus and Pearl Geysers, from which it is separated by a broad-topped hill. It belongs to another group, and is on a mound of hard white siliceous sinter, which, close to the spring, has a coating of ocherish-colored deposit. The water is somewhat opalescent. The appearance can be perfectly imitated by a solution of rosin in alcohol and water. It is alkaline in reaction, and is composed of the following constituents:

	Grams to liter.	Grains to imperial gallon.
Sulphuric acid	0.032	2.240
Chlorine	0.750	52.500
Silica	0.768	53.760
Calcium	0.034	2.380
Sodium	0.461	31.270

This may be arranged as follows:

	Grams to imperial gallon.
Sodium chloride	82.180
Calcium sulphate	3.220
Silica	53.760
Calcium chloride	4.060
	143.220

The quantity of silica in this water is so great that on concentration to a small bulk over a waterbath it gelatinizes and finally dries up to a mass resembling a pulverulent geyserite.

Table comparing waters from different geyser regions.

[Constituents are expressed in grains to the imperial gallon.]

Name.	Locality.	Silica.	Sodium chloride.	Potassium chloride.	Sodium sulphate.	Calcium sulphate.	Magnesium sulphate.	Sodium carbonate.	Aluminum phosphate.
Geyser at Haukadal	Iceland	37.80	17.22	....	10.22	....	....	.....	.....
Reikium	....do	21.70	20.51	....	12.11	.....	....	7.28	.....
Great Caldeira, Furnas Valley	St. Michael's, Azores.	20.80	94.64*	....	.....	.....	....	.....	.....
Te-puia-nui, at Tokanu	New Zealand	14.70	298.41†	....	.....	.....	....	.....	.....
Te-tarata, at Rotomahana	....do	11.48	175.28†	....	.....	.....	....	.....	.....
Rotopunamu, at Rotomahana	....do	16.17	83.44†	....	.....	.....	....	.....	.....
Otakapuarangi, or Pink Terrace, Rotomahana.	....do	43.95	93.55	1.05	1.01	10.96	....	.....	.54
Koroteoteo, at Ohinemutu	....do	22.40	66.34	1.46	7.49	.....	....	.....	.....
Kuirua, at Ohinemutu	....do	18.42	45.70	2.08	10.31	.....	.....	.....	Traces.
Old Faithful Geyser	Yellowstone N. Park.	9.80‡	.....	....	.....	.....	....	.....	.....
Pearl Geyser, Gibbon Basin	....do	7.84	61.39	....	1.89	1.40	....	.....	.....
Echinus Geyser, Gibbon Basin	....do	16.19	13.65	....	11.59	.....	....	.....	.....
Jug Spring, Lower Fire-Hole Basin	....do	14.56	31.57	....	.....	2.03	....	50.75	.....
Grand Geyser, Upper Fire-Hole Basin	....do	.....	.....	....	.....	.....	....	.....	.....
Opal Spring, Gibbon Basin	....do	53.76	82.18	....	.....	3.22	....	.....	.....

Name.	Locality.	Calcium and magnesium silicates.	Soda.	Aluminum oxide.	Calcium chloride.	Totals.	Analyst.
Geyser at Haukadal	Iceland	.....	6.65	3.26	.....	75.25	Black.
Reikium	....do	.....	.....	....	.....	61.60	Klaproth.
Great Caldeira, Furnas Valley	St. Michael's, Azores.	.....	.....	....	.....	115.44	Bullar.
Te-puia-nui, at Tokanu	New Zealand	.....	.....	....	.....	339.22	Kielmaier.
Te-tarata, at Rotomahana	....do	.....	.....	....	.....	191.24	Melchior.
Rotopunamu, at Rotomahana	....do	.....	.....	....	.....	120.82	Kielmaier.
Otakapuarangi, or Pink Terrace, Rotomahana.	....do	3.07[6]	.....	....	.....	154.13	Skey.
Koroteoteo, at Ohinemutu	....do	6.85§	.....	....	.....	104.54	Do.
Kuirua, at Ohinemutu	do	3.34§	.....	....	.....	79.85	Do.
Old Faithful Geyser	Yellowstone N. Park.	.....	.....	....	.....	.....	Heizmann.
Pearl Geyser, Gibbon Basin	....do	.....	.....	....	.....	72.52	Leffmann.
Echinus Geyser, Gibbon Basin	....do	.....	10.58[4]	....	.....	52.01	Do.
Jug Spring, Lower Fire-Hole Basin	....do	.....	.....	....	.....	98.91	Do.
Grand Geyser, Upper Fire-Hole Basin	....do	.....	.....	....	.....	57.77[5]	Peale.
Opal Spring, Gibbon Basin	....do	.....	.....	....	4.06	143.22	Leffmann.

*This includes an alkaline sulphate, and carbonate.
†Only silica and chlorine were computed. $MgCO_3$ and $CaCO_3$, and organic matter were proved.
§Silicate of iron and magnesia are included.
‡Contains also lime, a small quantity of iron, Al_2O_3,Mg, carbonates, sulphides, chlorides.
[4] Silicate of soda.
[5] Consists mainly of silica, with Cl, SO_4, Ca and Mg, and trace of Fe_2O_3.
[6] Traces of ferric oxide.

There are too few analyses to allow us to predicate much definitely, but, from this table, it would appear that our geysers are more like the New Zealand geysers than they are like the Iceland geysers in the composition of the water, especially as regards the proportion of silica, and as to sodium chloride they appear to be intermediate.

Table showing comparison of proportions of silica and total solid contents of thermal waters.

Locality.	Name of spring.	Country.	Grains of silica to the Imperial gallon.	Total solid contents in grains to the Imperial gallon.	° F. Temperature.	Analyst.
Gibbon Basin, Yellowstone Park.	Opal	United States.	53.76	143.22	90	Leffmann.
Rotomahana	Otakapuarangi	New Zealand.	43.95	154.13	208	Skey.
Haukadal	Geyser	Iceland	37.80	75.25	209	Black.
Do	do	do	36.40	60.90	.....	Damour.
Do	do	do	33.05	70.05	.....	Barruel.
Orakeikorako	Alum Cave	New Zealand	28.51	56.47	209	Skey.
Reikium		Iceland	26.11	59.29	.....	Black.
Do		do	21.70	61.60	.....	Klaproth.
	Store-Hver	do	22.40	45.50	.....	Damour.
	Hvergardin	do	22.40	44.80	.....	Do.
Whakarewarewa	Koroteoteo	New Zealand.	22.40	104.54	214	Skey.
Furnas Valley on St. Michael's	Great Caldeira	Azores	20.80	115.44	212	Bullar.
Orakeikorako	Pine Orakeikorako	New Zealand.	18.51	84.86	.....	Skey.
Ohinemutu	Kuirua	do	18.42	79.85	156	Do.
Reikium	Badstofa	Iceland.	18.20	36.40	.....	Damour.
Ohinemutu	Perckari	New Zealand.	18.17	56.00	150	Skey.
Do	Ariku-kapa-kapa	do	18.15	54.94	160	Do.
	Parke's Spring	do	16.73	200.73	.....	Do.
Gibbon Basin, Yellowstone Park.	Echinus Geyser	United States.	16.19	52.01	180	Leffmann.
Rotomahana	Rotopunamu	New Zealand.	16.17	120.82	63	Kielmaier.
Ohinemutu	Sulphur Bath	do	16.09	127.04	.....	Skey.
	McMurray's Bath	do	15.75	33.12	.....	Do.
Near Tokanu	Te-puia-nui	do	14.70	339.22	186.8	Kielmaier.
Mont D'Or		France	14.70	93.73	113	Berthier.
Lower Geyser Basin, Yellowstone National Park.	Jug Spring	United States.	14.56	98.91	190	Leffmann.
Ohinemutu	Te Kanwhanga	New Zealand.	13.86	66.38	204	Skey.
Rotorua	Te Kute	do	12.40	48.44	212	Do.
	Wapahahi	do	12.33	21.57	120	Do.
Rotomahana	Ruakiwi	do	11.76	172.34	210	Melchior.
Do	Te Tarata	do	11.48	191.24	214	Do.
Rotorua	Sulphur Bay Spring.	do	10.08	44.52	100	Skey.
Carlsbad	Sprudel	Bohemia	10.08	401.13	162.5	Göttl.
Rotoiti	Ruahine	New Zealand.	10.03	152.31	190	Skey.
Laugervalla	Langer	Iceland	9.80	16.10	.....	Damour.
Upper Geyser Basin, Yellowstone National Park.	Old Faithful Geyser.	United States.	9.80	.....	200	Heizmann.
Near Taupo	Near Otumuheka	New Zealand.	9.25	27.44	.....	Skey.
Savu-savu	Vanua Levu	Fiji Islands.	9.19	546.90	.....	Liversidge.
Rotoiti	Manuprua	New Zealand.	8.53	32.45	110	Do.
Chaudes Aigues		France	8.12	69.72	190.4	Berthier.
Near Taupo	Otumuheka	New Zealand.	7.86	13.80	.....	Skey.
Gibbon Basin, Yellowstone National Park.	Pearl Geyser	United States.	7.84	72.52	162	Leffmann.
Broosa or Prusia	Kukurtlu	Asia Minor	7.70	67.90	182	J. L. Smith.
Rotomahana	Cameron's Bath, near Otakapuarangi.	New Zealand.	7.01	130.35	115	Skey.
St. Nectaire		France	7.00	377.58	101	Berthier.
Near Taupo	Crow's Nest	New Zealand.	6.25	143.49	179	Skey.
	Te Hukahuka	do	6.10	13.81	.....	Do.
Red Creek, southwest of Pueblo, Colorado.	Parnassus Springs.	United States.	5.56	233.74	72½	Loew.
Hammam-Meschouten		Algiers	4.90	106.34	.....	M. Braun.
Aix la Chapelle	Kaiserquelle	Germany	4.87	302.07	131	Liebig.
Wiesbaden	Kochbrunnen	do	4.41	608.52	155¾	Fresenius.
Töplitz	Hauptquelle	Bohemia	4.25	46.05	120	Wolf.
Near Troy		Asia Minor	4.20	1,491.00	150	J. L. Smith.
	Te Mimi Okakahi	New Zealand.	4.12	29.51	112	Skey.

Table showing comparison of proportions of silica and total solid contents of thermal waters—Continued.

Locality.	Name of spring.	Country.	Grains of silica to the Imperial gallon.	Total solid contents in grains to the Imperial gallon.	Temperature.	Analyst.
Wagon-wheel Gap, Colorado.	.....	United States.	4.01	106.48	150	Loew.
Colorado	Pagosa Spring	....do	3.99	233 10	141	Do.
Gurgitello	.....	Ischia	3.92	518.21	149	Giudice.
Lebanon, New York	.....	United States.	3.89	29.21	73	Dussance.
Mammoth Hot Springs, Yellowstone National Park.	Cleopatra	....do	3.50	98.39	154	Leffmann.
Ems	Kesselbrunnen	Germany	3.45	203.47	115	Fresenius.
Mammoth Hot Springs, Yellowstone National Park.	No 17	United States.	3.36	83.30	165	Leffmann.
Olmitello	.....	Ischia	2.94	171.01	105	Giudice.
Broosa or Prusia	Tschekirghe	Asia Minor	2.80	38.50	113	J. L. Smith.
San Restitua	.....	Ischia	2.80	661.08	123	Giudice.
Bath	King's Bath	England	2.59	143.71	120	Philips.
Bagnères de Bigorre	La Reine	France	2.52	192.84	115.7	Gauderax and Rosière.
Schlangenbad	.....	Germany	2.47	24.53	89.6	Fresenius.
Yalova	.....	Asia Minor	2.45	98.77	156	J. L. Smith.
Apoquindo	.....	Chili	2.45	24.50	.....	
Gastein	.....	Austria	2.30	25.41	87–160	Wolf.
Hot Springs of Arkansas.	Washitaw Springs	United States.	2.23	10.08	93–150	Larkin.
Tarawera	.....	New Zealand	2.22	99.95	.....	Skey.
Bath County, Virginia	Healing Springs	United States.	2.18	42.81	88	Aikin.
Hamer's Plain, Nelson	.....	S. Island, New Zealand	2.11	86.41	.....	Skey.
Hot Springs, Virginia	Ladies' Boiler Bath	United States.	2.09	39.98	110	Gilhain.
Mytilene	Kelemyeh Oulunjah.	Asia Minor	1.05	87.50	102	J. L. Smith.
Colina	.....	Chili	1.12	21.96	.....	
Leuk	Lorenzquelle	Switzerland	.98	151.79	123	Brunner.
Plombieres	Source des Dames.	France	.85	19.29	125	Sheritier.
Ojos Calientes, 12 miles north of Jemez, N. Mex.	.....	United States	.70	162.54	119	Loew.
Hierapolis	.....	Asia Minor	.56	162.05	130	J. L. Smith.
Eski shehr	.....	....do	.56	18.20	119	Do.
Vichy	Grande Grille	France	.48	373.87	105.8	Bouquet.
Paso Robles, California	Main Spring	United States.	.44	77.40	112	Price.
Tiberias	.....	Asia Minor	.42	1,647.80	154	J. L. Smith.
Aix le basin	Eaux de Soufra	France	.35	30.04	108–111	Bonjean.
Ojos Calientes, 12 miles north of Jemez, N. Mex.	Geyser Spring	United States.	traces.	168.07	168	Loew.
Buxton	.....	England	.0	18.90	82	Scudamore.
Bristol	Hot Well	....do	.0	57.33	74	Carrick.
Toryla on Mytilene	.....	Asia Minor	.0	2,416.40	117	J. L. Smith.

SOLID CONSTITUENTS OF THERMAL WATERS.

There are only two or three of the many constituents of thermal waters to which we shall refer here in a brief consideration of their sources. To take up each one would require more space than we can spare. Silica is the characteristic element in the waters of very hot springs, especially in the geyser regions, not only in our own country but in every other. This, therefore, is entitled to the first place in this *resumé* of the subject.

SOURCE OF SILICA IN THERMAL WATERS.

The water found in geysers and hot springs being meteoric in its origin, we must look to the rocks through which it percolates for the source of its mineral ingredients. Springs with siliceous deposits are

found only in regions of volcanic rocks, and to them we turn. Chemical analysis shows all lavas contain silica in the proportion of one-half to four-fifths of their whole mass. Acid lavas contain 66 to 80 per cent. of silica. Basic lavas contain 45 to 55 per cent. of silica. When we examine the rocks of individual localities we find the same thing.

The following table gives some of them:

Locality.	Character of rocks.	Percentage of silica.
Iceland	Phonolite	72.3
Iceland	Palagonite	41.28
New Zealand	Rhyolites and trachytes	70.
District of Schemnitz, Hungary	Rhyolitic	70 to 81
Yellowstone National Park	Obsidian	77.*

*From an analysis by Dr. Leffmann.

But few of the rocks of the Park have been subjected to chemical analysis, but the microscope shows that they belong to the vitreous eruptive rocks.

Bunsen was of the opinion that the silica of these rocks could be dissolved only by alkaline waters. He digested some of the Iceland rocks in hot rain-water and obtained specimens identical with the water from the geyser.* Mr. Eugene Robert found the basin of an old spring near the Great Geyser in Iceland in which some of the rock had been altered to a substance resembling kaolin. Chancourtois analyzed both this and the unaltered rock. The latter contained 72.3 per cent. of silica and the former only 65.8 per cent. Robert therefore inferred that the silica in the water of the hot springs in Iceland was derived from the phonolite, basanite, &c. (See Bischof's Chemical Geology, vol. ii, p. 455.)

In the case of the deposits at Ischia and near Naples, Daubeny says the alkali supposed to be efficacious in dissolving the silica in the Iceland geysers, does not exist. In the Yellowstone National Park most of the springs whose waters were analyzed were alkaline, but one of them (Echinus Geyser, on Gibbon Geyser Basin) was decidedly acid, and yet it contained over 19 grains of silica to the gallon. When water is carbonated its solvent power is usually increased, but according to C. Struckman † silica dissolves more readily in pure water than in carbonated water. It must be rem emberedthat in the depths where the silica is dissolved by the water not only is there an enormous pressure but an intense heat. We can but faintly imagine the effects of the action of water upon the rocks at such high temperature and under such enormous pressure. Steam doubtless has a powerful agency in the work. Bischof found that the stones by which the Kaiserquelle at Aix la Chapelle is closed, and the canals of the Schwerdtbad, at Burtscheid (which consist of black marble), were converted into a doughy mass, on the inner side, by the continued action of the steam, which had a temperature of only 133° to 167° F.‡

This agrees with what we observed at the Gibbon Geyser Basin in the Park. At Spring No. 66 (see map of the Gibbon Basin, in Part I) is a

*M. Struve took a quantity of clink stone from near a spring at Bilin, in Bohemia, and after pulverizing it subjected it to the action of carbonated water, under a pressure of two atmospheres. Upon analysis it was found to agree closely in its composition with the water of the spring.

†Ann. Ch. u. Pharm. xciv, 337.

‡Researches on the Internal Heat of the Globe, p. 217.

deposit of *Pealite*, which was considerably fractured. On digging into it steam was noticed coming through the cracks, and on these surfaces the deposit was soft and could be cut with the knife like soap. This softening of the silica (the analysis shows it to be 75 per cent. of silica) was due to the effect of the steam.

During the eruption of Vesuvius in October, 1821, Monticelli and Covelli noted that fragments of lava when no longer hot remained separate, but when very hot *or traversed by hot vapors* they united so firmly that heavy blows of the hammer only could break them.*

SOURCE OF THE CARBONATES.

When the thermal waters are found in connection with limestones we find that they usually contain large percentages of calcium carbonate, which deposits in the form of calcareous tufa, the most common form of sediment found in connection with springs. All the springs in the Yellowstone National Park found with such deposits are found to have some connection with limestones. Carbonated waters coming in contact with silicates in granite, basalt, &c., subject them to a decomposition, and, as a result, the carbonates are formed.

SULPHUR AND SULPHURETED HYDROGEN.

Sulphur is a prominent constituent of many springs, and sulphureted hydrogen is, next to carbonic acid, the gas most frequently found in springs. Sulphur is supposed to be due to the decomposition of sulphides by the action of organic matter. In this connection it is interesting to note that the localities of the Yellowstone Park in which sulphur is characteristic are those where there are lake beds, that is, where the rocks were deposited at the bottom of lakes. This is especially the case in the Hayden's Valley springs. In connection with these sediments there is doubtless a considerable proportion of organic matter from the vegetation that once existed in the bottom of the old lake.

M. Eugene Planchud† believes the presence of sulphur is due to the reducing action of vegetable matter, basing his views upon the examination of the long, cylindrical sulphur threads found in the neighborhood of sulphur springs. It may be partly due, also, to the decomposition of sulphides by extremely hot water. In the Gibbon Geyser Basin we are led to suspect that the hot water must somewhere come in contact with sulphide of iron, which it decomposes. Iron and sulphur are abundantly present there.

ALUMINA.

As we have noted in a preceding portion of the report, the alumina of most of the springs is due to the fact of the water passing through beds of clay. Where the water contains sulphur we frequently have sulphides formed, as in the springs at Crater Hills in Hayden's Valley.

* Cited by Bischof, Internal Heat of the Globe [*loc. cit.*], p. 216.
† Vol. 41 Chemical News, p. 236.

SECTION III.—FORMATIONS AND DEPOSITS.

CHAPTER VIII.

PHYSICAL FEATURES OF DEPOSITS.

AMOUNT OF DEPOSITS.

The amount of sediment deposited by thermal springs seems almost incredible, especially in the case of calcareous tufa, which, as we have seen, is more rapidly deposited than the siliceous sinter. In 1604, Father Joseph de Acosta describes the springs of Huanvelica, Peru, as depositing stones of which houses are built.* In Hungary, also, where enormous deposits of both travertine and siliceous sinter are found, towns are built of it, and the same is true in Italy, where the deposits at San Vignone are quarried for building purposes.

Saint Peter's and all the principal buildings of Rome are constructed of Travertine or "Tiburstone."

In Carlsbad the hot springs have deposited masses of pisolitic rock (Strudelstein) which have filled up the whole bottom of the valley, and upon these deposits the town itself is mainly built.†

The deposits at the baths of San Vignone, Italy, have a thickness of 250 feet, and at San Fillipo, near Rome, entire strata of 328 feet thickness are found.

At Hamman Meskoutine, in Algiers, there are wall-like masses 4,921 feet long, 66 feet high, and from 33 to 49 feet in width. This is calcareous tufa.

At Clermont, in Central France, according to Le Coq, there are sixteen springs in four groups, and the deposit forms an aqueduct 300 feet long and 16 feet wide. The whole ground in some parts of Tuscany is coated with travertine, so that the ground sounds hollow beneath one's feet.

The deposits from the Bath spring, in England, if collected during the last 2,000 years, would, according to Judd,‡ form a solid cone equal in height to Monte Nuovo, in Italy. Professor Ramsay says that in one year the solid matter brought up by this spring is enough to form a column 9 feet in diameter and 1,440 feet high. In Virginia the springs have a deposit 30 feet in thickness. At Hierapolis the deposit of carbonate of lime rises 100 feet above the plain and has a width of 600 feet, and upon this the city stands. Back of this is another set of calcareous hills in which the springs are found. This is like the deposit at the Gardiner's River springs in the Yellowstone Park. The deposits here cover an area of about three square miles. The main mass is 200 feet high and over 300 yards in width, and this is but a small portion of the deposits, as a glance at the map of the Mammoth Hot Springs, in Chapter I, Part I, will show.

So far we have considered only the calcareous deposits. When we

* The Natural and Moral History of the Indies, &c., London, 1604; printed in London for the Hakluyt Society, 1880.

† Judd's Volcanoes, p. 184.

‡ Judd's Volcanoes, p. 219.

take a glance at the siliceous sinters we find that usually it is not so great in quantity. The deposits of the Great Geyser, in Iceland, according to Descloizeaux, in 1846, had a thickness of 13 to 16 feet, and the more ancient deposits had a thickness of over 80 feet.*

In New Zealand, Waikite, at Whakarewarewa, has a siliceous cone 100 feet in diameter and 15 feet high. Pohutu, at the same place, has deposits 20 feet in thickness. In the Azores a thickness of 30 feet of siliceous sinter is found.

In the Upper Geyser Basin of Fire Hole River, the Castle Geyser has a cone of 12 feet in height and a diameter of 20 feet on top and 120 feet circumference at the base. This cone is on a platform that measures 75 by 100 feet and is 3 feet in height, and the whole thing—cone and platform—is on a large mound of deposits that rise 40 feet above the level of the river and cover about 3½ acres.

The deposit in the mound on which the Giantess, Bee Hive, and Trinity Geysers are located occupies 22 acres, but it is of unequal thickness. The Trinity Geysers are 43 feet above the river level. At the Bee Hive the elevation is less, and at the Giantess more. The latter geyser has a depth of 63 feet. The table on page 369 gives the areas of other groups and shows the comparison with those of Iceland and New Zealand. We will now consider the rapidity of the deposition of these sediments.

RAPIDITY OF DEPOSITION.

Calcareous tufa.—As we have just noted, the deposits of calcareous tufa or *travertine* usually exceed in quantity the siliceous sediments. This is due mainly to the greater rapidity with which the former are laid down.

At the baths of San Vignone, in Italy, 6 inches of tufa is deposited yearly in the conduit pipes. At San Fillipo, in 20 years, a bed 30 feet thick has been formed in a pond.

At the Mammoth Hot Springs of Gardiner's River, in the Yellowstone Park, baskets and other articles of wire are placed in the overflow from Cleopatra Spring, and are coated with calcareous deposit. About one-sixteenth of an inch is deposited in four days under favorable circumstances. It would be impossible, however, to compute from this the age of the deposits at this locality, for under other circumstances the rate is much lower, and, again, it may frequently be more rapid in some other places.

Siliceous sinter or geyserite.—Forbes, who visited the Great Geyser of Iceland in 1860, placed a bunch of grass under a small fall where the ejected mass of water from the geyser drained rapidly away. He found that in twenty-four hours it received a coating of silica of about the substance of a very thin sheet of paper. He then made a calculation that, allowing 500 such sheets of paper to the inch, with the tube having a length of 762 inches, the age of the geyser would be 1,036 years. This calculation might be all right if the deposition took place regularly. But, as we shall see presently, the deposit occurs mainly when the water is allowed to evaporate, and this will occur most rapidly where the water rises and falls alternately, or when it frequently overflows from the basin. A reference to Fig. 28 (the figure explaining McKenzie's theory of the geyser) will help make this clear. This illustration gives a section of the Great Geyser. As the basin P is usually full, the evaporation will be more constant around the edges, which tends to build up the edge constantly. Whenever there is an

* John Coles gives the following for the size of the cone of the Great Geyser in 1881: 12 feet above the general level and 101 yards by 75 yards at the base. (See Summer Travelling in Iceland, &c. London, 1882.)

overflow the slope O will receive an addition. At K and S, the bottom of the basin and the sides of the tubes, the deposit will take place when the water is low and they are empty. This occurs only at comparatively few times. The rate, therefore, at O and S would be very different. The rate given by Forbes is what occurs under the most favorable circumstances. Ordinarily it is much less, but to what degree it is impossible to tell. It must be remembered, too, that there is no proof that the horizontal layers of sinter (or those that are comparatively horizontal) extend in that position to the bottom of the tube. Indeed, the layers added to the tube are laid on perpendicularly, *i. e.*, on the *sides* of the tube. Descloizeaux is inclined to give a great antiquity to even the newest deposits of the geysers in Iceland. He thinks that the increase within the historical period has been small, and in this opinion he is probably correct.

Mr. Josiah Martin, in describing the Pink Terrace or Otakapuarangi at Rotomahana Lake, in New Zealand, says the upper plateaus are inscribed with the names of tourists and the dates of their visits: "These slabs are perfectly smooth, and inscriptions in pencil become indelible under a coating of silica in a short time; but upon examining dates of twenty or thirty years since, the deposit of film was so thin as to be scarcely perceptible except as a thin glaze."*

Hochstetter, speaking of the Te Tarata, says that whatever lies upon the terraces becomes incrustated in a very short time. Miss C. F. Gordon-Cumming says that at Rotomahana the deposit is rapid, and fern leaves and sticks become thickly incrusted in a few days, as though they had been crystallized by a confectioner.†

These incrustations are found probably where the water is supplied rapidly, and can evaporate under favorable circumstances. We have no data as to the rapidity with which the formation of the siliceous deposits of the Yellowstone National Park occurs. That it varies at different places is evident, and without doubt the variations agree with those noted in other regions, especially Iceland and New Zealand.

On the plateau or terrace of the Fountain Geyser in the Lower Fire-Hole Basin in 1878 we found numerous inscriptions and names on the white deposits and in the shallow basins surrounding the Fountain Geyser. These had been written with lead-pencil by members of General Howard's command, which passed through the Lower Geyser Basin in 1876. When we saw them they were indelible, but the films of silica rendering them so were very thin indeed.

CAUSE OF THE DEPOSITS.

The main cause of the deposits, both calcareous and siliceous, is the evaporation of the water containing the carbonates and the silica. Calcareous or carbonated waters deposit also simply by cooling or by losing carbonic acid upon coming to the surface. In the specimen of water that we brought in from Cleopatra Spring (at Mammoth Hot Springs), after standing for three years sealed, there was a slight deposit of amorphous carbonates. In the specimen from Spring No. 17 (on the main terrace at Mammoth Hot Springs), after standing the same time, a small deposit of calcite was formed (see page 389).

Bunsen found that the geyser water from Iceland did not deposit upon cooling, and our experience was the same in 1871 with a specimen from the Grand Geyser, which was kept in a bottle for six months.

* The Geysers, Hot Springs, and Terraces of New Zealand, by Josiah Martin. Popular Science Review, October, 1879, p. 381.

† At Home in Fiji, p. 209.

GEYSERITES FROM SHOSHONE BASIN AND UPPER FIRE HOLE BASIN.

Our experience with the waters collected in 1878 shows that the waters from various springs differ upon this point. The following table will show at a glance the condition of the different specimens:

Spring and locality.	Percentage of silica in grains to imperial gallon.	Condition of water when the bottles were opened at the end of three years.
Jug Spring, Lower Fire-Hole Basin....	14.56	Perfectly clear; no deposit; alkaline in reaction.
Echinus Geyser, Gibbon Geyser Basin.	10.60	Perfectly clear; no deposit; acid in reaction.
Pearl Geyser, Gibbon Geyser Basin....	7.84	Perfectly clear; has a deposit of gelatinous silica, 2 tablespoonfuls to the imperial gallon; alkaline reaction.
Opal Spring, Gibbon Geyser Basin.....	53.76	This water presented the same opalescent appearance as when bottled; no deposit was found at the bottom of the bottle; alkaline reaction.

This would seem to prove that the mere fact of cooling has little to do with the throwing down of the silica, and that it is not due to the amount of silica in the water.*

The precipitation in the case of the water from the Pearl Geyser may be due to some chemical reaction taking place after the bottling of the water. Ordinarily the formation of the siliceous sinter or geyserite must be explained by the evaporation of the water as it flows from the springs or falls from the geyser. We must remember, however, that we have examined but a few of the many springs in the Park, and what may be true of the few cannot be arbitrarily stated as applying to all the others.

APPEARANCE OF GEYSERITES AND MODE OF FORMATION.

The deposits of the springs and geysers of the Yellowstone Park agree in general characters with those from other regions of siliceous springs. They are of almost innumerable variety, and to describe them here would be impossible. A few of the forms are shown in the accompanying plates (Plates XLIII, XLIV, and XLV), which have been engraved from photographs of the specimens. A very common form is that in which the general resemblance to a mass of cauliflower is striking; such specimens are seen in *a* and *b*, Plate XLIV. In the center of the plate (*c*) a similar formation is seen coating a piece of wood. The fracture of such specimens is very uneven, and the structure when they are broken is very irregular. On drying, they break readily into coarse granular pieces. They occur mainly in the vicinity of geysers where there is a fall of water. Where the surface is bathed in steam constantly they are usually pearly on the surface. In some places the surface has a porcelain-like appearance; in others a metallic appearance, as in the deposits of the Bronze Geyser. Where the flow from the spring is gentle a laminated structure is found. The layers are usually very thin. Some pieces resemble the fossil teeth of some huge herbivorous animal. In *f*, *h*, and *i*, Plate XLIV, and to the right *d*, in Plate XLIII, such specimens are illustrated. The orifices of geysers are usually beaded, and

*Le Conte, in his Elements of Geology, page 100, says that it is not true that silica deposits only on drying, "for the Yellowstone geyser waters, * * deposit abundantly by *cooling*, evidently because they contain much more silica than those of Iceland." We have in another place proved that the silica is about the same.

when there is much splashing over the edges, masses will be formed that when broken seem to be composed of bundles of siliceous stems, cemented together.

In the shallow pools surrounding some of the geysers pebbles are found. Some of these are very regular and very nearly spherical (see *d*, Plate XLIV), while others are very irregular, some being polyhedral. They are frequently covered with small nodules (see *a*, Plate XLIII). These may be formed in two ways: first, by constant surface accretions to a nucleus, which appears to be proved by the concentric structure of some that have been examined; or, second, as Professor Comstock suggests, they may have been worn down from forms with a more or less curved outline. He says:

> These pebbles have therefore been worn down to their present shape by attrition in their pools, and they have no doubt been first formed as ordinary mechanical deposits, in the form of protuberances over the general surface, or as divisions of a tessellated patch, like portions of the platform near the base of Old Faithful Geyser.*

In many basins there are irregular pieces of geyserite, smooth on their under surfaces, but beaded or covered with prickly points where they are exposed to the action of the water. They are loose in the basins, and may be divisions of a tessellated patch, as Professor Comstock suggests.

Mushroom-like forms are sometimes seen on the edges of the springs, and in the basins small columns (See *a*, Plate XLV) are found;† also rosette-like forms, with a connection between them and the bottom of the pool. Professor Bradley, speaking of these, says (see report for 1872, p. 240):

> Judging by their general appearance and conditions, these probably originate as fragments of very thin pellicles, formed by evaporation upon the very surface of the pool, and, broken up by the wind, each fragment tends to sink; but some of them escape that fate, and more material accumulates by evaporation upon their wet edges, so that they become basin-shaped and float securely. I cannot account for the basal spires about which a solid pedestal finally accumulates, except by supposing that they have central nuclei of the small fibers of *mycelium*, which are floating in all these pools in greater or less abundance.

Some specimens from the edges of the Pearl Geyser, in the Gibbon Basin, are made up of laminæ at the base, one of them being yellow and another white. Above these is a layer, irregular in structure, as though the water had fallen in drops while it was being deposited. The upper surface is different again. It is very irregular, of a porcelain-white color, and studded with small nodular points. This specimen, unlike so many of the geyserites, does not change by exposure. Four years after taking it from the spring it is as hard and compact as when collected. Its structure would appear to prove that the spring has had periods of very different sorts of action. The laminæ at the bottom indicate a simple overflow from the basin. This overflow may have been due to simple risings and fallings of the water in the basin. Then there appears to have succeeded a time when the water was in constant agitation, splashing over the sides. This, still later, was followed by a period of spouting, its present condition. These remarks might be extended almost indefinitely, but enough has been said to show that the forms are almost innumerable in their variety.

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* Reconnaissance of Northwestern Wyoming, &c., by Capt. W. A. Jones, 1873, p. 258.

†Similar small columns are seen in springs at Rotomahana, in New Zealand, and the Rev. R. Abbay (Jour. Geol. Soc., Vol. XXXIV, 1878, No. 34, p. 170–178) explains their formation as follows: He thinks the water is saturated with silica and has different temperatures. The water coming from two different basins meeting, a condensation occurs analogous to what occurs in the atmosphere when two masses of air, in which the temperatures are different, come together.

GEYSERITES FROM UPPER AND LOWER FIRE HOLE BASIN

MOUNDS AND CONES OR CRATERS.

A comparison of the various illustrations in Part I will show the great variety assumed by the cones and mounds of the geysers of the Yellowstone Geyser Basins. They may be simple basins, surmounting a tube, as in the case of the Grand and Saw Mill Geysers, sections of which are shown in Figs. 23 and 26*a*. In these geysers we really have no cones. Such is the case also in the Giantess (see Fig. 25), which is a huge globular basin or bowl in a mound of laminated geyserite. Others, as the Fountain Geyser of the Lower Geyser Basin, are basins with mounds just beginning to be formed where the water falls from the column during eruptions. The building up appears to be mostly on one side. A similar one-sided arrangement is seen in the crater of Old Faithful, as though the prevailing winds were from a certain direction, and caused the water to fall mainly on one side. In the Gibbon Geyser Basin there are geysers without any cones, or even any siliceous deposit, except what is just beginning to coat the rocks in which they are situated. This argues against Bunsen's theory that the deposit of silica is necessary to the existence of geysers. We shall have more to say of this farther on. Where we have mounds or cones we see that they present different characters. Compare, for instance, the cone of the Bee Hive with Old Faithful, or the Castle and Grotto with the Giant. In the Giant the cone is on a platform, and it seems as though before the latter was built the condition may have been similar to that of the Great Fountain, in the Lower Geyser Basin. The Castle also seems to have passed through several stages. To form the broad mound upon which its platform rests we must imagine a large bowl, with regular overflows to make the laminated deposits of this mound. Then, later, the platform was built on this mound, and still later again the cone or present crater of the geyser. None of the Yellowstone geysers present the simple form of the Great Geyser of Iceland (see section in Fig. 22), where a saucer-like basin surmounts a tube of 72 feet in length.

In the following table the sizes of the cones of the Yellowstone National Park are compared with the Great Geyser and some of the New Zealand cones:

Name.	Location.	Size at top.	Size at the base.	Height.
Union	Shoshone Geyser Basin		18 feet circumference.	3 feet.
Minute Man	do		46 feet circumference.	3 to 5 feet.
Clepsydra	Lower Fire-Hole Basin		10 by 15 feet	3 feet.
Flat, cone	do	55 feet diameter.		15 to 20 feet.*
Steep, cone	do	55 feet diameter.		20 to 25 feet.*
Bee Hive	Upper Fire-Hole Basin	3 by 4 feet	20 feet circumference.	3 feet.
Turban	do	11 by 23 feet		3 feet.
Grotto, cone 1	do		28 by 26 feet	8 feet.
Grotto, cone 2	do		19 by 26 feet	4 feet.
Giant	do	8 feet diameter.	24 by 25 feet	10 feet.†
Old Faithful	do	20 by 54 feet	145 by 215 feet	11 feet.
Castle	do	20 feet diameter.	120 feet circumference.	11 feet 11 inches.‡
White Pyramid	do			25 feet.
White Dome	Lower Geyser Basin			25 feet.
Great Geyser	Iceland	56 feet diameter.	101 by 75 yards	12 feet.
Waikite	New Zealand		100 feet	15 feet.

*These are in the Sentinel Group and have springs on their summits that are 8 or 9 feet in diameter, and have rims 6 to 8 inches high.

†These are dimensions of the cone only. It rests on a platform that is 4 feet high and has a circumference of 342 yards.

‡This rests on a platform measuring 75 by 100 feet, and 3 feet in height, and the whole mass, platform and cone, is on a mound of deposit 40 feet thick and covering 3½ acres.

Tyndall gives the following explanation of the manner in which the tube and crater of a geyser are formed:

> Imagine the case of a simple thermal siliceous spring, whose waters trickle down a gentle incline; the water thus exposed evaporates speedily, and silica is deposited. This deposit gradually elevates the side over which the water passes, until finally the latter has to take another course. The same takes place here, the ground is elevated as before, and the spring has to move forward. Thus it is compelled to travel round and round, discharging its silica and deepening the shaft in which it dwells, until finally, in the course of ages, the simple spring has produced that wonderful apparatus which has so long puzzled and astonished both the traveler and the philosopher.*

This mode of construction may explain the formation of some cones, but I am inclined to think the number few. A great majority of the basins have no overflow except when the springs are agitated, or when there are bulges of water, and then the overflow is equal in all directions, and, of course, the deposition of the silica in such cases is equal on all sides. Where there are waterways leading from the spring, as in the case of the Shield Geyser in the Shoshone Basin and others, there is usually a rim on each side of the outlet, and this is usually continuous with the rim of the spring. During the uplifting of the water, which causes the overflow, the water in the basin is usually up to the rim, and it is here that the evaporation causing the deposit takes place, and it goes on as rapidly as in the outlet. In springs that are usually quiet, and where the water stands at one level for a considerable time, the deposit, of course, being at the edge of the spring, there is a constant tendency towards narrowing the orifice, and the deposit will either curve towards the center of the spring, as we see in the edge of the beautiful Blue Spring of the Castle Group of the Upper Fire Hole Basin, or a flat edge will be found extending into the spring, as in the Columbia Spring of the Heart Lake Basin. This tendency to the closure of the opening of the spring is seen in the sections shown in the illustrations, Figs. 25 and 27.

To this tendency is due also the approximate conical forms of the craters and the globular form of the inclosed basin. They are all broader at the base than at the top. The water falling on the slope or outer curve, of course, deposits in layers conformable with it. Here we have, perhaps, the explanation of the peculiar form of the Bee Hive. In its eruptions the fall of water is very slight, and the greatest amount of deposition naturally takes place at the top of the cone. The character of the surface upon which the spring is located has much to do with the form of the mound. Where it is flat, dome-shaped masses will be the result as in the cones in the Sentinel group of the Lower Basin and in the White Dome and the White Pyramid. Where the spring or geyser is situated on a slope a series of terraces will be the result, as in the Te Tarata of New Zealand, and in the slopes of Old Faithful on a small scale. In the latter case the original form was a dome like those now seen in the vicinity. Old Faithful is probably of secondary origin, having broken out on the summit of an old mound which may possibly have become choked up. Where the slope is very gentle, as in that surrounding the Great Prismatic Spring of the Egeria Springs, the terraces are small and flat.†

Professor Bradley, finding near some of the geysers masses of volcanic sandstone perforated by irregular holes, which he attributed to the dissolving power of the hot water, thought that it represented, on a

*From "Heat a Mode of Motion."

†The lower terraces, at Rotomahana, on the lake shore, are shallower than at the top where the slope is greater.

TUFAS FROM MAMMOTH HOT SPRINGS AND GEYSERITES FROM FIRE HOLE BASIN

small scale, the process by which the large cavernous pools were excavated. He says:

It would appear that in many cases, at least, the hot alkaline (?) water, as it reaches the surface, is not thoroughly saturated with silica, and accordingly dissolves away the walls of its orifices so as to undermine the surrounding area, the surface of which falls in, until, in many cases, large caverns are excavated.*

It seems to me probable that the opening of the vents is generally due to a violent breaking out of a mass of steam and water, and that the size and character of the opening thus formed will depend upon the character of the rock and soil through which it forces its way. That geyser vents may be thus violently formed is proved by the steamboat vent of the Gibbon Geyser Basin which broke out in 1878. The Cliff Caldron or Excelsior Geyser in the Egeria Group of the lower Fire Hole Basin, in all probability, owes its origin to a similar violent outburst, as its basin is bordered on three sides by rough, irregular walls of laminated geyserite, which were evidently broken through by some force acting at right angles to the plane of their deposition.

The subject of the formation of the cones and craters of geysers is one of exceeding interest, and will require a great deal of study of the various forms. No place could be a better field for such study than is the Yellowstone National Park. We are well aware that we have done no more here than to indicate a few of the many thoughts suggested by a casual glance at the field indicated.

CHAPTER IX.

CHEMISTRY OF DEPOSITS.

By A. C. Peale, M. D., and Henry Leffmann, M. D.

The deposits from the thermal waters may be generally classed under three heads for the purposes of description here, viz: Travertine, Siliceous sinter, and Aluminous or Mud Deposits.

The first of these appears to be most widely distributed, and also occurs most frequently as an ancient deposit. In this chapter we will consider only the deposits of the Yellowstone National Park, except in the tables where a few analyses of calcareous tufas or travertines from other localities are inserted for the purposes of comparison.

TRAVERTINE.

Travertine, calc sinter, or calcareous tufa is always a deposit from springs or rivers, and, according to Dana (System of Mineralogy, p. 680), the name travertine is a corruption of *tiburtine* from *the Lapis Tiburtinus* of Vitruvius and Pliny.

The two principal localities of travertine in the Yellowstone National Park are the Mammoth Hot Springs of Gardiner's River and the Soda Butte of the East Fork of the Yellowstone River. Only one analysis was made from the specimens collected in 1878, and this is included in the following table, being the second one mentioned:

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* Report United States Geological Survey of the Territories, p. 235.

Table of analysis of travertines or calcareous tufas.

Locality.	Analyst.	CO_2	SiO_2	H_2O	Al_2O_3	Fe_2O_3	CaO
Manmoth Hot Springs of Gardiner's River, Yellowstone National Park	Endlich	30.35	3.32	1.75	3.31	3.62	57.70
Do	Leffmann			0.3			54.2
Spring near Medway, in Utah	Woodward	41.73	2.49		0.22		53.22
Grass Valley Spring near Bardmass Pass, Nevada	do	39.07	8.70		0.26		48.32
Tufa Dome in Pyramid Lake, Nevada	do	38.52	6.90	1.20	2.54		47.48
Steamboat Spring on Bear River, Idaho				5.98		1.05	92.55*

Locality.	Analyst.	MgO	Na_2O	KO	PO_4	SO_4	Totals.
Mammoth Hot Springs of Gardiner's River, Yellowstone National Park	Endlich	Trace.	Trace.				100.05
Do	Leffmann	Trace.					97.10
Spring near Medway, in Utah	Woodward					2.38	100.00
Grass Valley Spring near Bardmass Pass, Nevada	do	3.98					100.33
Tufa Dome in Pyramid Lake, Nevada	do	2.50	0.48	0.19	Trace.	Trace.	99.81
Steamboat Spring on Bear River, Idaho		0.42*					100.00

*From Fremont's Report.

SILICEOUS SINTER.

Siliceous sinter, fiorite, or geyserite, as the siliceous deposits of thermal waters are variously called, is abundant in most of the spring localities of the park, especially in the geyser basins of Fire Hole River.

Fiorite, the name given by Thompson to the pearly siliceous deposit from near Santa Fiora, in Italy, has the priority. The deposits, however, are so characteristic of the regions that *Geyserite*, the name given by those who first analyzed specimens from Iceland, has been most frequently used. No matter which name is used, fiorite or geyserite is a variety of opal, and in it, perhaps, is to be seen the condition of first stages of the more typical opals. A careful study of the various geyserites, especially the older specimens, found in the geyser basins of the Yellowstone National Park, will probably throw light on the subject of the formation of opal. In the Heart Lake Basin I found a geode, the outside of which was a hard geyserite (*Pealite*), while the interior was filled with semiopal. In the Iceland region (at Haukadal), chalcedony was found by Descloizeaux in clay, and he was of the opinion that opals and chalcedonies found in some ancient volcanic districts might have had their origin in a similar way.

According to Bischof, opal may be compared to a solidified mass of gelatinous silica, in which, according to the extent of desiccation, the amount of water may vary much. He also says that the occurrence of opal in fissures shows that it has been deposited from water. Hydrophane, a translucent light-colored opal found in Saxony, is said to be so soft in the mine that it will receive the impression of a hard substance.

In the Yellowstone National Park we find first the silica in solution in the hot waters, next the form of gelatinous silica, as in the specimen described under the name of *Viandite*, examined by Mr. Goldsmith. Next to this come geyserites of all textures, some being very soft, especially those recently deposited. Where the deposits are older they are harder and grade into *Pealites*, a subvariety named in 1872 by Dr. F. M. Endlich, and placed by him between quartz and opal. *Hyalite* is also found in the Gibbon Basin in connection with *Pealite* as an alteration of the

original deposit of one of the springs. The analyses of the waters have already been considered, and we now take up the deposits, beginning with *Viandite.*

VIANDITE (Goldsmith n. s.).

Before giving Mr. Goldsmith's remarks and analysis I will refer briefly to its mode of occurrence. Its appearance is described by Mr. Goldsmith as seen in the specimens that are still moist. When dried it resembles somewhat leather, although it is more brittle. It is found in sheets surrounding some of the springs where the surface is flat enough to allow the water to stand and become cool. In other places it occurs in long waving fibers, or in sponge-like forms. It is rusty-brown, reddish, or pink, and even greenish, and sometimes pure white.

A glance through the chapters in Part I of this report will show that it is found in the Geyser Basins of the Fire Hole in the Shoshone Basin, and on the shores of the Yellowstone Lake, as well as in the Grand Cañon of Yellowstone. The specimen described and analyzed by Mr. Goldsmith is from the Shoshone Geyser Basin, where it was taken from the mound of deposit on which the south group is located.

Most writers, in speaking of this curious deposit, are inclined to consider it a vegetable growth, and compare it to mycelium or the mother of vinegar.

VIANDITE, A NEW VARIETY OF SILICA.

By E. Goldsmith.

A specimen of a very peculiar looking material was collected by Dr. A. C. Peale in the Shoshone Geyser Basin, Yellowstone National Park, on the 25th of August, 1878. Dr. Hayden forwarded it to Professor Joseph Leidy, who transferred it to me for investigation. The material had been packed in a small tin box, and, although not hermetically sealed, may have been preserved in such a state as it was originally found. The soft moist substance has not the appearance of a mineral; it looks like a partly decomposed meat with bits of fat intermingled. The color is partly brown and gray, with patches of white irregularly distributed. It is so soft that it may be easily compressed with the fingers, by which process some water is separated. After such pressing it remains flat, showing, therefore, no elasticity. The odor is somewhat foul, but not strong. I determined the specific gravity with 1.729 grams of substance and found it to be 1.120.

When 10 grams of the material were exposed on steam during sixteen hours, there remained but 2.457 grams; hence 24.57 per cent. of dry substance, and 75.43 per cent. of loss, which is nothing else but water.

The dried substance is softer than talc, and is porous. It crumbles easily between the fingers to fine powder. The color of the powder is straw-yellow. It is tasteless and has no odor. Specific gravity was found with 0.483 gram of the substance to be =1.312.

When pieces of the dry substance are thrown on water they remain floating on the surface until they absorb some of the water, when they will sink, but they seem to possess a certain buoyancy.

Blowpipe reactions.—When heated in a closed tube it affords a dense gray cloud which condenses partly into water and partly to an oily matter. In thin layers the oil is yellow, in thicker, dark brown. The odor of the fumes are penetrating strong, tary; the straw-yellow powder became black. When heated on platinum foil it changes to black first, which quickly disappears, leaving a white powder. Heated on charcoal, it showed no sign of fusion. Fused with sodium corbonate, it forms a glassy slag with a faint bluish coloration, indicating a trace of manganese. With solution of cobalt there is also produced a pale-blue coloration. In microcosmic salt it is but partially soluble; the bead is slightly pinkish in both the oxidizing and the reducing flame.

Hydrochloric acid, as well as sulphuric acid, do not dissolve the substance. In order to bring it into solution it was fused with carbonate of soda and treated as a silicate.

Under these circumstances I recognized the following oxides: silica, alumina, iron, lime, traces of magnesia, and manganese.

Quantitative analysis.—1.100 grams of the steam-dry substance lost, on ignition, 0.164 grams=14.91 per cent. of organic matter, with probably some water. After

fusion with carbonate of soda I separated 0.8825 grams of silica = 80.22 per cent.; next 0.036 grams of a mixture of alumina and sequioxide of iron = 3.27 per cent.; finally, 0.005 grams of lime = 0.45 per cent. The manganese and magnesia were not determined in quantity, but are counted into the loss = 1.15 per cent.

Bringing the results into a column:

	Per cent.
Silica	80.22
Alumina and iron	3.27
Lime	0.45
Loss on ignition	14.91
Manganese, magnesia, and loss	1.15

From these datas the original substance would have the following composition:

	Per cent.
Water	75.43
Silica	19.71
Alumina and iron oxide	0.80
Lime	0.11
Organic matter	3.67
Manganese, magnesia, and loss	0.28

The water and silica make up the principal part. It is = 95.14 per cent., and the remaining substances seem to be mixed with this hydrosilicic acid. The pure hydrosilicic acid would therefore have the composition: Silica = 20.72 per cent., oxygen = 11.04 per cent., water = 79.28 per cent., oxygen = 70.47 per cent. The ratio 11.04 : 70.47 1 : 6.38 may serve to formulate the compound.

$$[(\ddot{S}i)\,\dot{H}^{13}.]^*$$

It is very probable that this compound possesses no stability when exposed to a dry atmosphere. Part of the water will evaporate and thus change the relative proportions of its constituents. The same is the case with other hydrous minerals. The object in view was to determine the soft, flesh-like looking unknown substance just as it was collected and received. The name suggested is nothing but a fancy on account of its peculiar appearance as the substance represents itself.

Beneath the microscope the substance appears, by transmitted light, in very small, rounded, and occasionally in elongated granules, which reminded me of the yeast plant, so far as the form is concerned, but its source and composition excludes the idea of being that organic matter.

GEYSERITES.

Under this head are presented the analyses of the recent deposits of the geysers and springs of the Park. These were made by Dr. Leffmann. A large collection of specimens was brought in, but as we could only have a limited number of analyses made, we selected specimens mainly from those places from which specimens had never been analyzed. Specimens from the other parts of the Park were analyzed in previous years, and the results are incorporated in the tables which follow the analyses enumerated here. The latter will be considered according to their localities.

Upper Geyser Basin of Fire Hole River.

The only analysis we present is of a specimen from spring No. 24 in the Three Crater Group. It is a red-mud spring, which is at the bottom of a cave-like depression. The water is a thin reddish mud, which splashes against the sides, forming red stalagmitic processes or points.

ANALYSIS.

(Color, red; fracture, uneven; hardness, 4.)

	Per cent.
Silica	86.9
Water and organic matter	8.0
Iron and aluminum susquioxides	3.6
	98.5

* Expressed in modern formula, $H_4SiO_4 + 11\,H_2O$.

Omitting the sesquioxides the proportion of the silica will be about 91 per cent., thus showing the specimen to be a geyserite.

Gibbon Geyser Basin.

Three specimens of geyserite from this basin were analyzed, and they are probably the first analyses ever made of specimens from this locality.

Specimen from Echinus Geyser.—The deposit from the water of Echinus Geyser occurs as a thin coating on the rocks surrounding its basin. It is usually lead-color or reddish.

ANALYSIS.

(Color, red; fracture, uneven; hardness, 5.)

	Per cent.
Silica	73.0
Water	11.0
Iron and aluminum sesquioxides	13.5
	97.5

Omitting the sesquioxides the relation of the silica and water will be—

Silica	87.0
Water	13.0

showing the specimen to be a somewhat impure geyserite. Iron is a prominent constituent in this specimen, and yet in the water no iron was detected. (See analysis, page 391). The water is acid, and the iron may be due to its action upon the surrounding rocks.

Pearl Geyser.—The deposit surrounding this geyser is greenish-gray, yellowish-white, and pearly. The specimen analysed has laminated layer at the base, yellowish and resinous in appearance; above this it is greenish-gray, with an irregular hard white surface, something like coral.

ANALYSIS.

(Fracture, irregular; hardness, 6.)

	Per cent.
Silica	87.1
Water	10.6
Alumina, Lime, Iron oxide	undetermined.
	97.7+

The specimen contains a trace of sulphides which blacken a silver dish when the finely powdered mineral is heated in it to 212 F.° Hydrogen sulphide is evolved in small amount when the mineral is heated with acid.

Spring No. 25.—White specimen; laminated in structure; fracture uneven; hardness, 5.

ANALYSIS.

	Per cent.
Silica	90.1
Water	8.0
Iron and aluminum oxides	traces.
	98.1

Shoshone Geyser Basin.

Only one specimen from this Basin was subjected to analysis, but it came from one of the most interesting springs—the *Bronze Geyser* or spring. It is surrounded by nodular masses which have a bronze-colored surface, the metallic appearance of which is striking. It is re-

tained; specimens kept three or four years showing it as well as the fresh specimens.

ANALYSIS.

(The specimen is in convoluted layers, with bronze-colored surfaces; the bronze layers alternate with whitish ones. The powder is fawn-colored. Hardness, 5.5.)

	Per cent.
Silica	83.1
Aluminum and iron sesquioxides	1.2
Organic matter and water	13.6
	97.9

On heating to 212° F. the powder loses 5 per cent.; a high heat causes it to turn gray and give out a distinct odor of nitrogenous organic matter. The iron and aluminum appear to be in union with this organic matter.

Heart Lake Geyser Basin.

The analyses, three in number, of specimens from this basin are the only ones published up to the present time. They are the following:

Rustic Geyser.—The specimen is an oval, or egg-shaped, pebble from the outer basin of the Rustic Geyser.

ANALYSIS.

(Color, chalky-white on surface, porcelain-like inside; fracture irregularly conchoidal; hardness, 5.5.)

	Per cent.
Silica	90.0
Alumina and iron oxides	2.6
Lime	1.6
Water	5.0
	99.2

Rustic Geyser.—Specimen from the edge of the geyser, when fresh. This geyserite was translucent, resembling rock-candy in appearance more than anything else. When dry, however, it became opaque and white.

ANALYSIS.

(Hardness, 5.5 to 6.)

	Per cent.
Silica	87.3
Water	10.3
Aluminum and iron oxides	2.2
	99.8

Deluge Geyser.—This specimen is from the outer basin of the geyser, and is a light-pinkish laminated deposit, with rosette-like projections or nodules on the surface.

ANALYSIS.

(Hardness, 5.)

	Per cent.
Silica	89.00
Water	8.00
Lime, Iron, Aluminum	undetermined
	97.00

In the following table I have endeavored to present all the anlyses of the Yellowstone geyserites that I could find. There are included several analyses of Nevada deposits made by Mr. Woodward, taken from the reports of the Survey of the Fortieth Parallel. Following this table are tables of the New Zealand and Iceland geyserites.

Table of analyses of geyserites from Yellowstone National Park, and other parts of the United States.

Locality.	Analyst.	Year of analysis.	SiO_2.	H_2O.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	SO_4.	LO.	Cl.	SrO.	MnO.	Total.
Lower Geyser Basin of Fire Hole River	Peale	1872	83.83	11.02									4.00			98.85
Do	Hitchcock	1872	87.56	9.30	1.65		0.55	0.46	0.48							100.00
Do	Austen	1872	87.14	9.79	1.67		0.49	0.23	0.68							100.00
From Giant Geyser, upper Geyser Basin, of Fire Hole River	Endlich	1873	92.64	6.25	Trace.	0.60	1.03	Trace.	Trace.					Trace.		100.52
Do	Endlich	1873	79.56	13.42	0.46	Trace.	1.54	1.78	Trace.				Trace.			97.76
Cauliflower Spring, lower end of Upper Geyser Basin of Fire Hole River	Peale	1873	86.10	12.20	1.96	0.71	0.28	Trace.	Trace.	Trace.		Trace.				101.25
Between Fountain Geyser and Mud Puffs, Lower Geyser Basin of Fire Hole River	Peale	1873	88.48	10.40	0.88	Trace.	0.18	Trace.	Trace.	Trace.		Trace.				09.94
Round Ball, from Great Fountain Geyser, Lower Geyser Basin of Fire Hole River	Peale	1873	88.60	9.00	1.60		0.95	Trace.	Trace.	Trace.		Trace.				100.15
Black specimen from ravine above the Great Fountain Geyser, Lower Geyser Basin of Fire Hole River	Peale	1873	82.80	8.99	5.64	1.49	2.13	Trace.	Trace.	Trace.					Trace.	101.05
Brown specimen from Sentinel Group, back of Twin Buttes, Lower Geyser Basin	Peale	1873	85.85	9.75	1.94		1.85	0.30	Trace.	Trace.		Trace.				99.69
Bank of Pelican Creek, near Yellowstone Lake (red and white specimen)	Heizmann		70.00		29.54		.13	Trace.								
Bed of Pelican Creek, near Yellowstone Lake (white nodule)	Heizmann		75.55	9.50	Trace.	Trace.	Trace.	Trace.								
Spring on Pelican Creek, near Yellowstone Lake (green, white, and brown specimen)	Heizmann		83.00	11.00			Trace.									
White irregular ball from Shoshone Geyser Basin	Peale	1873	85.75	12.00	2.20		0.85	Trace.	Trace.	Trace.		Trace.				100.80
Blue specimen from Shoshone Geyser Basin	Peale	1873	76.80	13.00	9.46	Trace.	1.80	Trace.	Trace.							101.06
Bronze Geyser in Shoshone Geyser Basin	Leffmann	1881	83.10	13.60	1.2											97.9
Reddish deposit from Echinus Geyser (No. 45) Gibbon Geyser Basin	Leffmann	1881	73.00	11.00	13.50											97.5
White deposit from near Opal Spring (No. 25) Gibbon Geyser Basin	Leffmann	1881	90.10	8.00	Traces.											98.1

* Na Cl.

Table of analyses of geyserites from Yellowstone National Park, and other parts of the United States—Continued.

Locality.	Analyst.	Year of analysis.	SiO_2.	H_2O.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	SO_4.	LO.	Cl.	SrO.	MnO.	Total.
From Pearl Geyser (No. 70) Gibbon Geyser Basin	Leffmann	1881	87.10	10.60	Undetermined.											
Pebble from bowl of Rustic Geyser, Heart Lake Geyser Basin	Leffmann	1881	90.00	5.00	2.6		1.6									99.2
Deluge Geyser, on Witch Creek, Heart Lake Geyser Basin	Leffmann	1881	89.0	8.00	Undetermined.											
Edge of Rustic Geyser, Heart Lake Geyser Basin	Leffmann	1881	87.3	10.30	2.2											99.8
Red specimen from Muddy Spring (No. 24), in Three Crater Group, Upper Geyser Basin of Fire Hole River	Leffmann	1881	86.9	8.00	3.6											98.5
Hot spring, near Ruby Lake, Nevada	Woodward		88.79	7.33	1.75	Traces.	0.80		1.06	0.27						100.00
Steamboat springs, Nevada	Woodward		92.67	5.45	0.80		0.14	0.05	0.75	0.18						100.04
Steamboat springs, Nevada	Woodward		92.67	5.47	0.65		9.18	0.05	0.99	0.15						100.25
Steamboat springs, Nevada	Woodward		90.11	7.56	0.72		0.41	Trace.	0.46	0.26						99.53
Steamboat springs, Nevada	Woodward		90.42	7.55	0.53		0.33	Trace.	0.37	0.27						99.47

Table of analyses of Iceland geyserites.

No.	Analyst.	SiO_2.	H_2O.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	SO_4.	Total.
1	Klaproth	98.00		1.50	0.50						100.00
2	Kersten	94.01	4.10	1.70							99.81
3	Damour	92.59	7.41								100.00
4	Bickel	91.56	5.76	1.04	0.18	0.33	0.47	0.16	0.19	0.31	100.00
5	Damour	91.23	8.97								100.22
6	Bickel	88.26	4.79	0.69	3.26	0.29		0.11	0.11	2.49	100.00
7	Damour	87.67	10.40	0.71		0.40		0.82	trace.		100.00
8	Forchhammer	84.43	7.88	3.07	1.91	0.70	1.06	0.92			99.97

NOTE.—These analyses are taken from Dana's Manual Nos. 1 and 2; resemble *Pealite* in their proportion of silica and water, but we do not know their physical structure.

Table of analyses of New Zealand geyserites.

Spring and location.	Analyst	SiO_2.	H_2O.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	Total.
Near Lake Taupo	Mallet	94.20	3.06	1.58	0.17	trace.		0.85*		99.86
Whatapoho at Lake Rotomahana	Mayer	88.02	7.99	2.99		0.64		0.40		100.04
Otakapuarangi at Lake Rotomahana.	Mayer	86.80	11.61	trace.	trace.	trace.	trace.	trace.	trace.	98.41
Te Tarata at Lake Rotomahana	Mayer	86.03	11.52	1.21		0.45	0.40	0.38	0.38	99.99
Te Tarata at Lake Rotomahana	Mayer	84.78	12.86	1.27	1.27		1.09	1.09		100.00
Great Ngahapu at Lake Rotomahana	Mayer	79.34	14.50	3.87	1.34	0.27	0.26	0.42		100.00
Near Lake Taupo	Pattison	77.35	7.66	9.70	3.72	1.74				100.17

*Na Cl.

PEALITE.

In 1872 specimens were obtained from the lower exposed layers in the platform of the Giant Geyser in the Upper Fire Hole Basin that were harder than any obtained before, and had a close resemblance to opal. The specimens were white, red, and green, and were examined by Dr. F. M. Endlich, who analyzed them and named them *Pealite.** In 1878, similar specimens were obtained from the Shoshone Basin, the Heart Lake Basin, the Gibbon Basin, and the Fire Hole Basins. Some of these specimens were analyzed by Dr. Leffmann, and the results are presented below.

No. 1. *Specimen from near the Black Sand Geyser, in the Upper Geyser Basin of Fire Hole River.*—This specimen is of a pinkish color, somewhat translucent in places, having a hardness of 6.5 to 7 and a fracture somewhat conchoidal.

ANALYSIS.

	Per cent.
Silica	94.0
Ferric oxide	1.0
Water	5.3
	100.3

No. 2. *Specimen from Yellow Crater Spring, in the Shoshone Geyser Basin.*—This specimen has an opaque, porcelain-like appearance, and occurs scattered over the mound in small pieces, reminding one of broken china.

*Report of U. S. Geol. Survey of the Territories for 1872, p. 153.

ANALYSIS.

(Hardness, 6.5 to 7.)

	Per cent.
Silica	94.0
Lime and ferric oxide	1.0
Water	5.2
	100.2

No. 3. *Specimen from the head of branch of Witch Creek, in the Heart Lake Geyser Basin.*—This specimen was found on a bank or side of a hill where the springs were all dead, and the deposits were evidently older than in most other parts of the basin.

ANALYSIS.

(Hardness, 7.)

	Per cent.
Silica	94.1
Water	1.0
Alumina, lime, iron, undetermined.	
	95.1+

No. 4. *Specimen from No.* 66, *Gibbon Geyser Basin.*—This specimen came from the site of an old spring, one that has probably been dead for many years. In connection with the specimen, hyalite is found, which is evidently a spring deposit much altered.

ANALYSIS.

(Fracture, conchoidal; hardness, 5.5; color, white.)

	Per cent.
Silica	95.4
Water	2.5
Aluminum and iron oxides, traces.	
	97.9+

The following table gives the comparison of these specimens with the type specimen, and with quartz, and opal, and geyserite:

Specimens.	Silica.	Water.	Hardness.
No. 1	94.0	5.3	6.5 to 7
No. 2	94.0	5.2	6.5 to 7
No. 3	94.1	1.0	7
No. 4	95.4	2.5	5.5
Type specimen (report of 1872)	95.0	1.5	6 to 6.5
Geyserite	87.0	10.0	5.1
Opal	93.0	7.0	5.5 to 6.5
Quartz	99.0	0.3	7.0

The next table presents, for comparison, all the analyses of Pealites that have been made:

Table of analyses of "Pealites" from Yellowstone National Park.

Locality.	Analyst.	Year.	Specific gravity.	Hardness.	SiO_2	H_2O	Al_2O_3
Platform of the Giant Geyser, Upper Fire Hole Geyser Basin.	F. M. Endlich...	1873.	2.4	6.0 to 6.5	95.84	1.50	Trace.
Platform of the Giant Geyser, Upper Fire Hole Geyser Basin.	F. M. Endlich...	1873.	2.08	6.0 to 6.5	.....	6.30	.....
Near the Giantess, Upper Fire Hole Geyser Basin.	C. L. Heizmann.	1873?	.....	.....	93.00	6.00	.....
Near the Black Sand Geyser Spring, Upper Fire Hole, Geyser Basin.	H. Leffmann	1881.	2+	6.5 to 7	94.00	5.3	.....
Yellow Crater Spring, Shoshone Geyser Basin.	H. Leffmann	1881.	2+	6.5 to 7	94.00	5.2	.....
Witch Creek, Heart Lake Geyser Basin.	H. Leffmann	1881.	2+	7	94.1	1.00	*
No. 66 Spring, Gibbon Geyser Basin.	H. Leffmann	1881.	2.03	5.5	95.4	2.05	Trace.

Locality.	Analyst.	Year.	Fe_2O_3	CaO	LO	Na_2O	Total.
Platform of the Giant Geyser, Upper Fire Hole Geyser Basin.	F. M. Endlich...	1873.	2.68	Trace...	Trace	Trace.	100.02
Platform of the Giant Geyser, Upper Fire Hole Geyser Basin.	F. M. Endlich...	1873.	.....	.....	.....	.....	.....
Near the Giantess, Upper Fire Hole Geyser Basin.	C. L. Heizmann.	1873.	.....	.....	.....	.....	†99.00
Black Sand Geyser Spring, Upper Fire Hole Geyser Basin.	H. Leffmann	1881.	1.00	.....	.....	.....	100.3
Yellow Crater Spring, Shoshone Geyser Basin.	H. Leffmann	1881.	1.00	1.00	.....	.....	100.2
Witch Creek, Heart Lake Geyser Basin.	H. Leffmann	1881.	*	*	.....	.....	.....
No. 66 Spring, Gibbon Geyser Basin.	H. Leffmann	1881.	Trace.	.....	.....	.....	97.9

* Undetermined.

† This analysis has been included, although it is not certain that it is anything more than an old geyserite which has lost a great deal of its water. Dr. Heizmann describes the specimen as being velvety drab on the surface, and of a pearly luster in the interior. It has been put in on account of its agreeing so closely with the other specimens in the proportion of silica and water.

ALUMINOUS DEPOSITS.

In another portion of the report we have mentioned the fact that whenever the thermal waters come to the surface through a thickness of soil, we find the springs having the character of mud springs. Of course the chemical composition of the water will have some effect upon the soil through which it passes, and modify it.

No specimens from the collections of 1878 were submitted for analysis, so that we have nothing new to present under this head.

In the table following the analyses of mud deposits from the Yellowstone National Park are given and compared with one of the French mud springs. In Germany and France mud springs are said to be very efficacious in the cure of certain diseases, and our springs may have similar effects. We know so little, however, of the chemical composition of the mud springs of the Park that nothing definite can be predicated here concerning them.

Table of analyses of deposits of mud springs.

Locality.	Spring.	Analyst and date.	SiO_2.	H_2O.	Al_2O_3.	Fe_2O_3.	CaO.
Yellowstone National Park.	White specimen; spring unknown.	A. Steitz	42.2	.....	.....	.....	17.8
Do	Lavender specimen; spring unknown.	....do	22.2	5.2	58.6	.6	4.2
Do	Pink specimen; spring unknown.	....do	32.6	2.5	52.4	.....	8.3
Do	Pink specimen; mud puffs, Lower Geyser Basin.	F. M. Endlich, 1873.	44.61	8.65	45.09	1.86	Trace.
Do	Blue specimen, near Castle Geyser, Upper Geyser Basin.	....do	50.70	15.15	20.27	3.25	Trace.
Bourbonne, in France.	.....	.....	64.00	.....	.....	5.00	6.00

Locality.	Spring.	Analyst and date.	MgO.	Na_2O.	K_2O.	H_3BO_3.	SO_4.	Total.
Yellowstone National Park.	White specimen; spring unknown.	A. Steitz	33.4	6.6	6.6	...	.....	100.00
Do	Lavender specimen; spring unknown.	....do	.....	.....	....	3.2	.....	.....
Do	Pink specimen; spring unknown.	....do	.....	4.2	4.2	...	.....	100.00
Do	Pink specimen; mud puffs, Lower Geyser Basin.	F. M. Endlich, 1873.	2.66	Trace	....	...	.....	102.87
Do	Blue specimen, near Castle Geyser, Upper Geyser Basin.	....do	11.55	.....	....	...	Traces.	100.92
Bourbonne, in France.	.....	.....	.....	*15.00	....	...	.....	†90.00

*Organic.
†This is given as contained in 100 parts. The remainder (10) is probably water, although it is not mentioned. The analysis is taken from Walton, p. 350.

SECTION IV.—GEYSERS.

CHAPTER X.

DEFINITION OF GEYSERS AND THEORIES.

DEFINITION.

We have in Part II, page 306, given the derivation of the word Geyser from the Icelandic word *geysa*—to gush. We now come to the definition of a geyser. It may be defined to be a periodically eruptive or intermittent *hot* spring from which the water is projected into the air in a fountain-like column. The analogy between geysers and volcanoes has frequently been noticed and the former have often been described as volcanoes which erupt heated water instead of melted lava. We have italicized the word hot in the definition just given, because springs containing a large amount of gas may simulate geysers.*

*The Kane Geyser Well in Pennsylvania is an instance. It spouts regularly, the eruptions being due to gas. An artesian well at Rank Herlany, in Hungary, which is 1,457 feet deep, the highest temperature of which is 75° F., spouts to the height of 100 feet at regular intervals. It contains more carbonic acid gas than water in its volume.

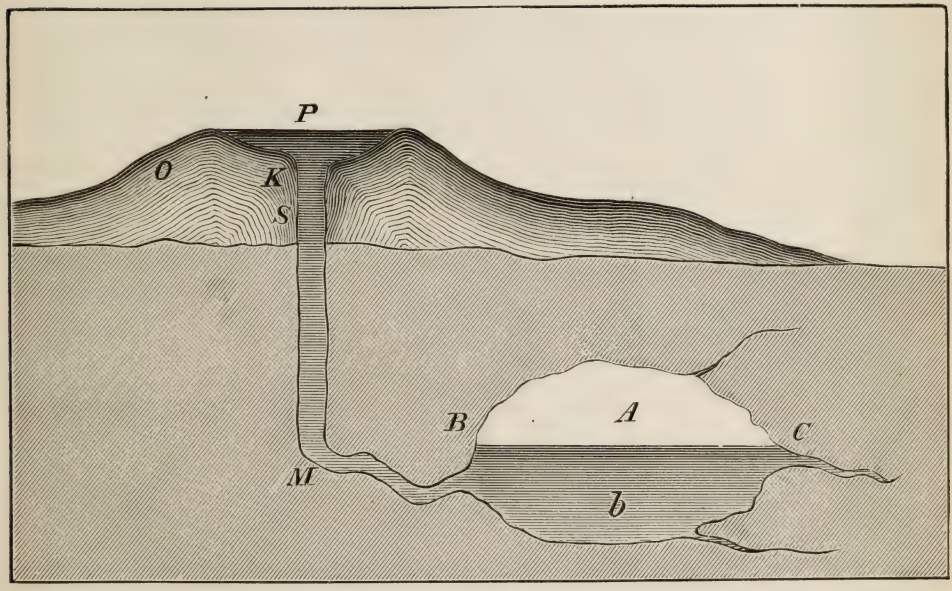


FIG. 28.—Section of Great Geyser of Iceland, illustrating MacKenzie's theory.

The difference between geysers and ordinary hot springs is not readily explained, nor even always recognized. The difference between a quiet thermal spring and a geyser in active eruption is very marked, but between the two there is every grade of action. Some geysers at times appear as quiet springs, as for instance the Grand Geyser during its period of quiescence. Others might easily be mistaken for constantly boiling springs, as in the case of the Giant Geyser, in which the water is constantly in active ebullition. This is true also of the Strockr of Iceland. Many of the springs, therefore, that in the Yellowstone Park have been classed as constantly boiling springs may be unsuspected geysers. The Excelsior Geyser was not discovered to be a geyser until eight years after the setting aside of the Park. Almost all constantly boiling springs have periods of increased activity, and those which spurt a few feet into the air have been classed as *pseudo-geysers*.

It has been noticed that geysers occur where the intensity of volcanic action is decreasing. In the neighborhood of active volcanoes, such as Vesuvius, the temperature appears to be too high, and the vapor escapes as steam from what are called stufas.* When the rocks at the surface are more cooled the water comes forth in a liquid form.

We will now pass to the consideration of the various geyser theories that have been proposed by different writers.

GEYSER THEORIES.

Herschell's theory.—The first theory I shall give here is one suggested by Sir J. Herschell.†

An imitation of geyser jets may be produced on a small scale by heating red hot the stem of a tobacco pipe, filling the bowl with water, and so inclining the pipe as to let the water run through the stem. Its escape, instead of taking place in a continued stream, is then performed by a succession of violent explosions, at first of steam alone, and as the pipe cools, almost wholly of water. At every such paroxysmal escape of the water a portion is driven back, accompanied with steam, into the bowl. The intervals between the explosions depend on the heat, length, and inclination of the pipe; their continuance on its thickness and conducting power. The application of this experiment to the geysers requires that water percolating through fissures and crevices in the earth should reach a fissure in which the rock is red hot. Steam would then form and force its way to the surface, carrying with it some of the water, and also drawing some of it back towards the source. After the steam was all condensed the water would return, and a repetition of the phenomena would take place.

McKenzie's theory.—Sir George McKenzie visited the Iceland geysers in 1810, and in 1811 he proposed the following as the explanation of their intermittent action:

He supposed that the geyser tube P M (Fig. 28) communicated with a cavity (A), to which meteoric water had access from the surface by means of fissures. The walls of this cavern are hot from the nearness of the seat of volcanic fire, and also receive heat from steam that comes into it by fissures at the bottom. This steam, having an extremely high temperature, heats the water in A to and above the boiling point. The water stands at the level B C, and the space above it is filled with steam

*The steam from stufas usually has temperatures far above the boiling point of water.

†MSS. read to Geol. Soc. of London February 29, 1832, cited by Lyell in Principles of Geology, p. 555.

under high pressure. This pressure is sufficient to sustain the column of water P M to the height P. If there is a sudden addition of heat under *b*, a quantity of steam will be produced in starts and the expansive force will be so great that the water will overflow at P. All the water in *b* will be forced into the pipe, and the steam will rush through it with great violence, and the eruption takes place. The shaking of the ground and the noises like the discharge of artillery he refers to the evolution of steam in starts, due to the sudden accessions of heat.

McKenzie admitted that his theory could only be a partial explanation. He, however, recognized the fact that the sudden evolution of steam is the proximate cause of the eruptions. He could not account for the frequent and periodical production of the phenomena. Bunsen thought that McKenzie's theory would account for the action of the Little Geyser, but not for the eruptions of the Great Geyser.

Bischof's theory.—Very similar to McKenzie's theory is the one adopted by Bischof in his Researches on the Internal Heat of the Globe (pages 227, 228). It is really the theory of Krug Von Nidda, who examined the geyser in 1833. Bischof says:

> He [Krug Von Nidda] takes it for granted that these hot springs derive their temperature from the aqueous vapors rising from below. When these vapors are able to rise freely in a continued column the water at the different depths must have a constant temperature equal to that at which water would boil under the pressure existing at the respective depths; hence the constant ebullition of the permanent springs and their boiling heat. If, on the other hand, the vapors be prevented by the complicated windings of its channels from rising to the surface; if, for example, they be arrested in caverns, the temperature in the upper layers of water must necessarily become reduced, because a large quantity of it is lost by evaporation at the surface, which cannot be replaced from below. And any circulation of the layers of water at different temperatures, by reason of their unequal specific gravities, seems to be very much interrupted by the narrowness and sinuosity of the passage. The intermitting springs of Iceland are probably caused by the existence of caverns, in which the vapor is retained by the pressure of the column of water in the channel which leads to the surface. Here this vapor collects, and presses the water in the cavern downward until its elastic force becomes sufficiently great to effect a passage through the column of water which confines it. The violent escape of the vapor causes the thunder-like subterranean sound and the trembling of the earth which precedes each eruption. The vapors do not appear at the surface till they have heated the water to their own temperature. When so much vapor has escaped that the expansive force of that which remains has become less than the pressure of the confining column of water, tranquillity is restored, and this lasts until such a quantity of vapor is again collected as to produce a fresh eruption. The spouting of the spring is therefore repeated at intervals, depending upon the capacity of the cavern, the height of the column of water, and the heat generated below.

Bischof says that the eruptions of the *Geyser* and *Strockr* agree exactly with this explanation, and he accounts for the two distinct classes of eruption observed in the *Geyser* as follows:

> The two distinct classes of eruption in the *geyser* which we have already mentioned seem to be attributable to two different cavities. A smaller cavity fills quicker, and, therefore, empties itself more frequently; a larger one fills slower, empties itself seldomer, but with greater violence.

Bunsen's theory.—In July, 1846, Bunsen and Descloizeaux spent eleven days in studying and experimenting upon the Great Geyser of Haukadal, in Iceland. They took temperatures at different points in the tube. These temperatures are given on the right-hand side of the column in Fig. 22. On the middle left-hand side are the figures that represent the boiling points of the water for the different depths, calculated according to the ordinary laws. Bunsen's first conclusions are that—

(1) The temperature in the geyser tube increases as we descend.

(2) At no point does the water in the tube attain the temperature of ebullition which it should have under the pressure to which it is sub-

jected, but the temperature depends on the time that has elapsed since the last eruption. As a great eruption comes near it approaches the boiling point.

(3) At a depth of about 45 feet the difference between the temperature of the water and the calculated boiling point for that pressure is the least.

Mr. Walker, in 1874, verified Bunsen's results. His temperatures are given in Fig. 22, on the left. He found the smallest difference at a depth of about 39 feet.

In Fig. 31 these temperatures are shown in curves. The temperatures are represented on A B, and the depth of the tube is measured on B D. The curve *a b* represents the calculated boiling points at the different depths. The following are the other curves (the letters referring to those in Fig. 31):

k k shows the temperatures recorded by Walker.

The following are the curves showing Bunsen and Descloizeau's temperatures:

c m d, July 6, 1846, 0^h. 30^m. a. m., three hours after a great eruption and eleven hours before the next one.

c e, July 6, 1846, 8.20 a. m., nine hours after a great eruption and twenty-three hours before the next one.

c f, July 7, 1846, 2.55 p. m., four hours before a great eruption.

c g, July 7, 1846, 6.58 p. m., ten minutes before a great eruption.

c s d, July 7, 1846, 9.45 p. m., two hours after a great eruption.

Of these curves, *c e* is farthest from the curve of the boiling point, and it shows the temperatures at *twenty-three* hours before an eruption; *c g* approaches the curve of the boiling point most closely, and records the state of the tube at *ten minutes* before the eruption takes place.

Now, this being the state just before the eruption takes place, there can be no doubt that at the time it does occur, it must actually reach the boiling point, *i. e.*, the curve *c g* must touch the curve *a b*. Bunsen accounts for this as follows: He supposes that the column in the central tube communicates by a long and sinuous channel with some space, be it what it may, which is subjected to the action of the direct source of the subterranean heat. The temperature gets raised above the boiling point, due to the pressure, and a sudden generation of steam is the result. This steam rises in the column of water, which, being cooler, causes it to condense. Gradually the heat of the water is raised until the water of the channel must boil, and the steam therefore cannot condense, but must accumulate and acquire a gradually increasing tension. The condensation of the bubbles possesses a periodic character, and to this is due the uplifting of the water in what Bunsen calls conical water-hills, which are accompanied by the subterranean explosions. The water in the tube, by the influx of heated water, is gradually brought so near the respective boiling points for the pressures under which it is that a very slight shock is sufficient to carry a certain layer to a point of the tube where its temperature would be in excess of that required to vaporize it, and the result would be a sudden and violent generation of steam. A rise of only a few feet near the middle of the column would be sufficient to cause the instantaneous generation of an additional volume of steam, which would rush upwards and thus relieve the pressure of the strata beneath and thereby contribute to the production of more steam. The enormous force (calculated to be equal to that produced by an engine of 700-horse power) is not expended in one effort, but there are several successive eruptions, the

whole lasting for several minutes.* The strata of water, being successively relieved of the pressure, rise and flash into the gaseous form, one after the other, until the ebullition has descended from the middle of the tube to a point near the bottom. That there was no motion, or scarcely any motion, below while the violent eruption was taking place above was proved by letting down to various depths stones suspended on strings. Those sunk to points near the bottom of the tube were undisturbed, while those nearer the surface were cast out to great heights. Bunsen even allowed his thermometer to remain at the bottom of the tube and it was undisturbed† during a great eruption, which reached the height of 142 feet.

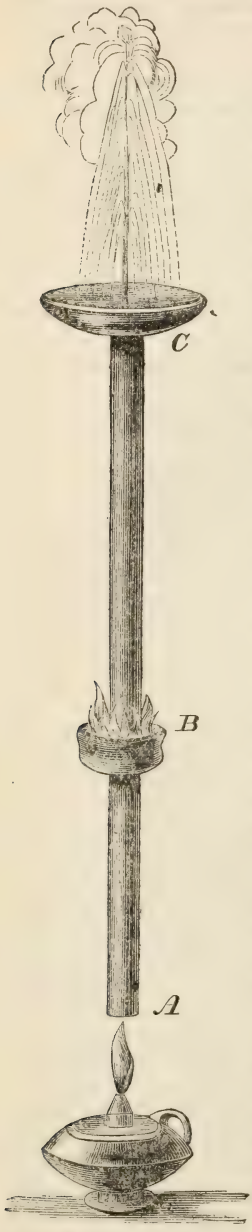


FIG. 29.—Artificial Geyser.

Prof. J. H. J. Müller, of Freiburg, constructed an artificial geyser to demonstrate Bunsen's theory. Fig. 29 represents an artificial geyser. If an iron tube, A C, about 6 feet in length, is surmounted by a basin and filled with water, when heat is applied at two places, A and B, the phenomena of a geyser eruption will be reproduced. The heating at B is to represent the point of nearest approach to the boiling point in the geyser-tube, while the heat at A imitates the high temperature at the bottom of the geyser. The difference, therefore, between the natural and the artificial geyser is that in the former the effect is not necessarily due to two distinct sources of heat, as the two fires A and B in the illustration, but is caused by the continual influx of heat from the bottom or side of the shaft. Although there is a circulation of water in the tube, there is not an equalization of the heat throughout it. This is due in part to the impeding of the circulation by the roughness of the walls, and partly because the water is freed by long boiling from all mixture of air, especially at the bottom of the geyser.

Comstock (in report of Captain Jones on Northwestern Wyoming, p. 257) thinks Bunsen's theory has not yet been proven adequate to explain the more prominent features of geyser eruptions. Nor does it, in his opinion, account for all the differences between geysers and hot springs, and he proposes a structural hypothesis which combines Bischof's and Bunsen's theories. Fig. 30 is an illustration taken from his report (p. 256), and is intended to represent the supposed condition of the subterranean geyser waters in the first stage of an eruption. The reservoir *d* contains water, which remains in equilibrium at the level shown in the illustration. "By constant accessions of heat from below, the vacant passage above is finally filled with vapor, and by degrees the water in the bent passage *b* be-

* The description of the eruptions is given in Chapter I, Part II.
† The explanation of this curious fact will be given on a succeeding page.

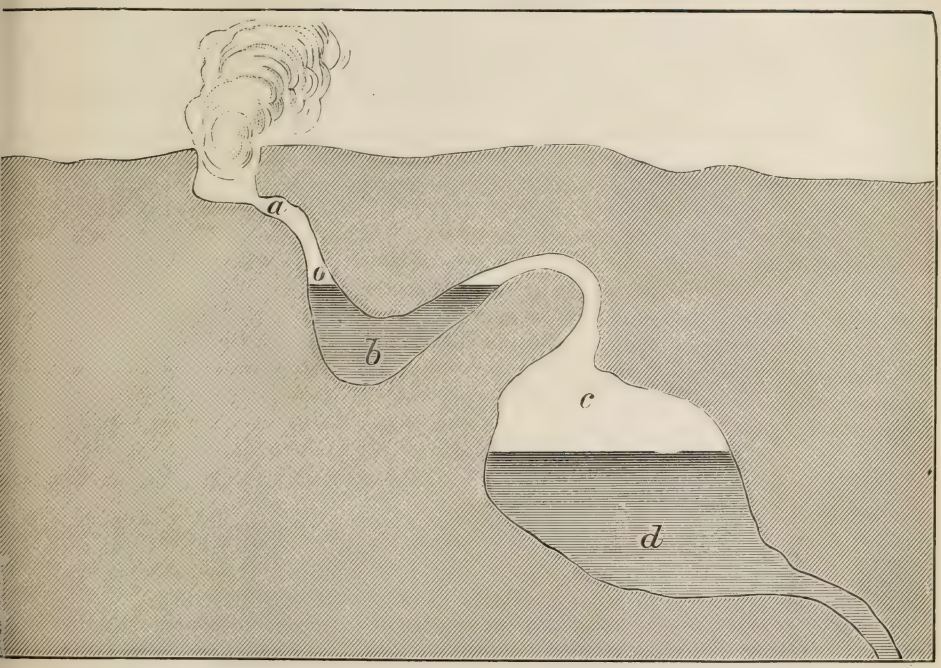


FIG. 30.—Diagram illustrating Comstock's idea of intermittent geyser action (from Jones's Report).

comes heated and evolves vapor also, as in *o*. After a time the expansion of the vapor in *c* is able to overcome the combined pressure of the water and vapor in *b* and *o*, when the latter is forced out, followed by a portion of the water in the reservoir *d*. The force thus expended, a vacuum is produced in *c* by the receding of the column of water in *d*, and the foregoing operations are indefinitely repeated." "The passage *b* may be kept filled with water by means of the surplus which falls back into the bowl."

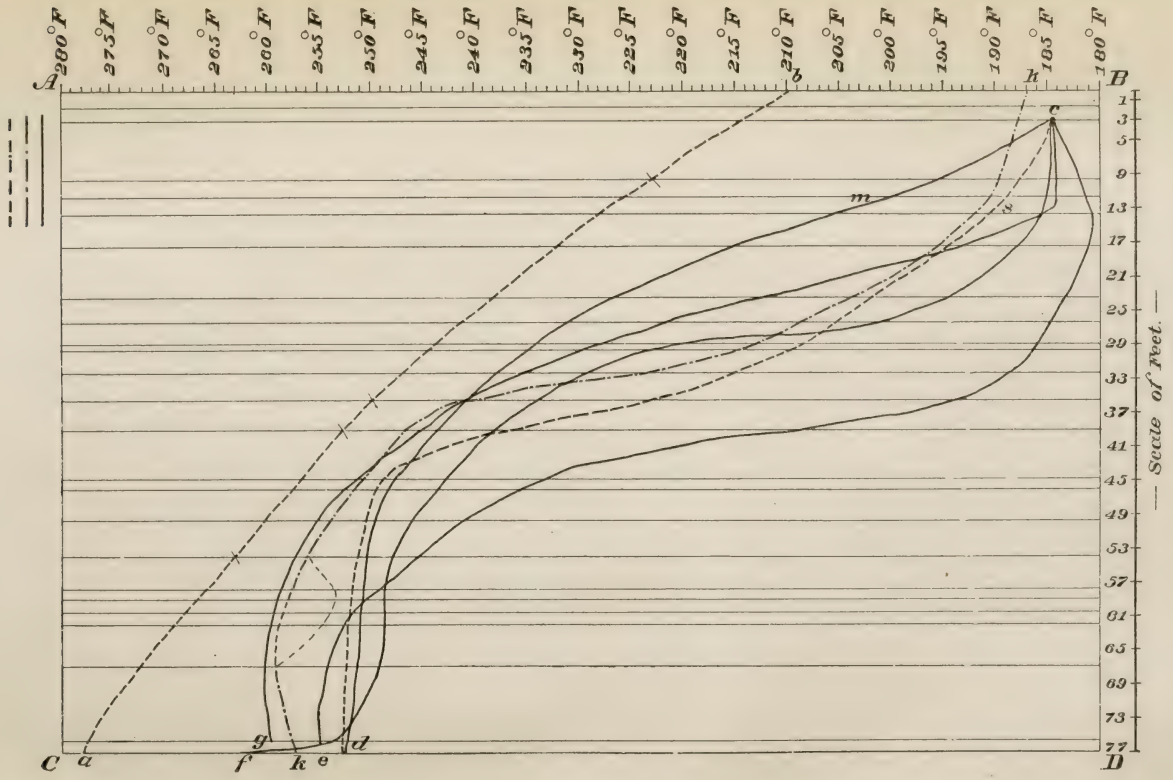
This idea of Professor Comstock supposes that an escape of vapor is the first indication of an eruption, followed by a rising of the water so as to fill the surface chamber of basin of the geyser. In most cases the steam that comes from the geysers is the result of the violent boiling of the water whose surface is a short distance below the bowl or basin. In many geysers the first intimation of an eruption is the bulging and boiling of the water at the surface, as in the Grand and Fountain Geysers. In Old Faithful, spurts of water, due to abortive attempts at eruption, are the precursors of eruptions. In the Union Geyser violent boiling and spurts of some considerable height were constant for two days preceding the eruptions. The steam period, instead of occurring before the eruption, is characteristic in most cases of the close of the eruption.

Baring-Gould's theory.—S. Baring-Gould, who visited the Iceland geysers in 1863, thinks that a bent tube is sufficient to explain the action of the Great Geyser. He took an iron tube and bent it at angle 110°, keeping one arm half the length of the other. He filled the tube with water and placed the short arm in the fire. For a moment the surface of the liquid remained quiet, and then the pipe began to quiver; a slight overflow took place, without any sign of ebullition, and then suddenly, with a throb, the whole column was forced high into the air. With a tube, the long arm of which measured 2 feet, and the bore of which was three-eighths of an inch, he sent a jet to the height of 18 feet. Steam is generated in the short arm and presses down the water, causing an overflow until the steam bubble turns the angle, when it forces out the column in the long arm with incredible violence. This is an adaptation of McKenzie's theory.

Of the theories that we have just enumerated, perhaps no one is adequate to explain all the phenomena of geyser action. Bunsen's theory comes nearest to it, and in the simplest kinds of geysers is a sufficient explanation. The variations and modifications in the geyser tubes and subterranean water passages must undoubtedly be important factors entering into any complete explanation of geyser action. Now, of course, we can see what the conditions are at the surface, but in our experiments we can penetrate to a very inconsiderable distance. We have, therefore, no data to present on these points, and investigations of this branch of the subject will have to be carried on in an artificial manner; that is, artificial geysers will have to be constructed, and various modifications made in the tubes until results are reached analogous to those seen in the natural geysers. If water in a glass tube be heated with rapidity from the bottom, it will be expelled from the tube violently, and if boiled in a kettle which has a lid and a spout, either the lid will be blown off or the water will be forced out through the spout. The first case is an illustration, in part at least, of Bunsen's theory, and the second exemplifies the theories which presuppose the existence of subterranean cavities with tubes at or near the surface. According to the former we must suppose that the layer of rock, extending 75 to 77 feet

below the surface, contains sufficient heat to account for the geyseric phenomena, or else that the geyser tube has some opening either at the bottom or on the sides, by which steam and superheated water have access to it from a considerably greater depth where the temperature is very high. At these depths caverns probably exist. In "Frost and Fire," page 417, Vol. II, it is stated that in the tube of the Great Geyser of Iceland, at a depth of 45 feet from the surface, there is a ledge which was first discovered by Mr. Bryson, of Edinburgh. From beneath this ledge steam bubbles rise while the geyser tube is filling, and a thermometer sunk a few feet below it was lifted and driven about like "a fish in a flurry," and when brought to the surface was found to be broken. The conclusion is that steam or hot water or both enter the tube from the side just beneath this ledge, for when the thermometer was sunk lower it remained quiet. Here, then, we have an explanation of the quiet and safe condition of Bunsen's thermometer at the bottom of the geyser during a great eruption (see page 421). Strockr has openings on opposite sides of its tube, and when empty, water and steam can be seen pouring into it from both apertures. In Fig. 32, taken from "Frost and Fire," sections of both Strockr and Geyser are shown. The point 45 feet below the surface is important in Bunsen's theory, and here is the ledge from beneath which water and steam are supposed to enter the tube. The Great Geyser is usually full of water, and consequently its internal construction cannot readily be examined, but there is little doubt that it is similar to that of Strockr, *i. e.*, it consists of a tube with a conduit or conduits leading to subterranean cavities. That such cavities exist is more than probable. On page 405 I have indicated my belief, that all geysers are originally due to a violent outburst of steam and water, and, under such conditions, irregular cavities and passages are more likely to be formed than regular tubes. As a fact, geyseric action on a small scale, dependent on an arrangement of cavities and tubes, may be simulated by heating water and plaster of Paris together in a tin pan. For details of such experiments, see pages 405–407 of "Frost and Fire."

In view of what we have just written, Bunsen's conclusion (No. 2) given on page 418, would have to be modified somewhat. His conclusion was that, at no point in the tube did the water attain the temperature of ebullition which it should have under the pressure to which it is subjected. As far as this relates to the straight tube in which his temperatures were taken, it may be so; but if he could have taken temperatures in the side conduit, I have little doubt he would soon have reached a point where the temperature would not only be at the boiling point for that depth but even exceed it. In the Yellowstone Park we obtained a number of *surface* temperatures which were above the boiling point. In the Great Geyser of Iceland, the mass of water in the tube prevents this condition at the surface, and when it takes place opposite the aperture an eruption is caused. In the main, however, I am inclined to accept Bunsen's theory, especially as it seems to me to require subterranean cavities in which the water must be heated. Whether these are caverns, enlargements of tubes, or sinus channels, appears to me to be of no consequence, except as the interval or period of the geyser might be affected by the form of the reservoir holding the water. In the following chapter a few points relating to variations of the water supply are given.



A B shows the temperatures, *B D* depth of geyser tube.
Curve *a b* is the curve of the boiling points.
Curve *k k* shows the temperature recorded by Walker.
Curve *c m d*, July 6, 1846, $0^h\ 30^m$ a. m., three hours after a great eruption and eleven hours before the next one. Bunsen and Descloizeaux.
Curve *c e*, July 6, 1846, 8.20 a. m , nine hours after a great eruption and twenty-three hours before the next one. Bunsen and Descloizeaux.
Curve *c f*, July 7, 1846, 2.55 p. m., four hours before a great eruption. Bunsen and Descloizeaux.
Curve *c g*, July 7, 1846, 6.58 p. m., ten minutes before a great eruption. Bunsen and Descloizeaux.
Curves *c s d*, July 7, 1846, 9.45 p. m., two hours after a great eruption. Bunsen and Descloizeaux.

FIG. 31.—Diagram giving curves of temperature observed in Great Geyser of Iceland.

CHAPTER XI.

Peculiarities of Geyser Eruptions.

DIFFERENCES BETWEEN GEYSERS.

In the Iceland geysers the eruptions assume a simpler form than in our own region, and Bunsen's theory appears in the main to be a sufficient explanation of the action. The question is, whether or not this theory will satisfactorily account for the differences observed in the geysers of the Yellowstone National Park. There are in the park four classes of geysers, when they are grouped according to the characteristics of their eruptions, without regard to the lengths of the intervals. In the following table we give this classification:

Characteristics of eruptions.	Geysers.
1. Geysers in which the action is confined to one eruption, *i. e.*, a distinct period of water eruption, characterized by a succession of jets, which follow each other rapidly, and are not followed by a marked steam period.	Old Faithful. Bee Hive.
2. Geysers in which the eruptions consist of a single water period, as in the preceding cases, but which are followed by a marked steam period of considerable length.	Castle.
3. Geysers which have several water eruptions, separated by an interval of several minutes or hours, while the regular interval is from a day to several days.	Grand. Giantess.
4. Geysers with water periods as just stated, but which are followed by a marked steam period.	Giant. Union.

EXPLANATION OF DIFFERENCES.

In the foregoing table we have included only the most prominent of the geysers. With the limited data at hand we do not presume to offer any final explanations of the differences that we have just tabulated. We are of the opinion, however, that at the bottom of the explanations, lies the question of the water supply and the arrangement and shape of the tube and passages, be they simply caverns or enlargements of the tubes. In the case of Old Faithful Geyser these are most simple. The supply of water must be regular and constant, and the tube of such shape and dimensions that the same conditions recur with great regularity. The Castle Geyser differs from Old Faithful and the Bee Hive mainly in the fact that it has a long steam period, during which the steam pours out or is pushed from the geyser throat with great violence and a terrific noise. There appear to be only two possible explanations of this difference, viz, either an accumulation of immense volumes of steam in the castle, or an instantaneous formation of steam throughout the length of the geyser tube. The former, to our mind, is untenable, because it seems impossible that the water, which is exhausted in fifteen minutes, should exert enough power to keep down the immense amount of steam that violently escapes without cessation for more than an hour. According to Bunsen's theory, it can be readily explained. The relief afforded by the first part of the eruptions allows the superheated water to rise rapidly, and before it can reach the top or orifice of the tube it is

all converted into steam from the top downward with inconceivable rapidity, and must be forced out with the terrific violence which is noted in the case of the Castle. On page 208 we have expressed the opinion that it is the oldest geyser in the region, and it seems to us that a greater length in the tube, with a consequent greater supply of water, will account for the difference between the Castle and Old Faithful, the latter of which we consider one of the youngest geysers in the Upper Geyser Basin (see page 221).

When we attempt to explain the differences between classes 3 and 4 and 1 and 2, *i. e.*, between those geysers that have a single water eruption and those that have several periods or phases in each eruption, we meet with greater difficulties. It may be partially explained by assuming that there are several reservoirs from which the water is supplied to the geyser tube. These reservoirs must be quickly emptied into the geyser tube and slowly refilled to explain the action, and here some modification of McKenzie's idea may be the true one. The water in these supposed reservoirs must be in such thermic condition that a comparatively short time in the actual geyser tube is sufficient for the production of the necessary conditions for an eruption.

Irregularities in the size and shape of the geyser tube leading to the basin or bowl at the surface must necessarily have considerable influence on the eruptions. In a perfectly straight tube there would not be apt to be as great differences in the temperatures of the different parts of the tubes as in one which was very irregular. The form of the crater or bowl seems to modify but little, if any, the action of the geysers, except as to the form of the column or mass of water thrown up into the air. In those cases like the Giantess, where the bowl contains a large mass of water, of course there is more resistance to the escape of the lower layers in which the geyseric action is occurring. We can readily see how the appearance of the ejected mass of water would thus depend, to a great extent, upon the character of the containing bowl, while the effect upon the phenomena occurring in the subterranean passages would be slight. We can imagine its having some effect upon the length of the intervals, but the fact remains that a geyser may consist of a simple tube, as in the Bee Hive, or a tube with an expanded basin at the top, as in the Grand, Old Faithful, &c., or as an immense reservoir of water above a tube, as seen in the case of the Excelsior, Giantess, Oblong, and others.

CHAPTER XII.

Influences modifying Geysers.

EFFECT OF THE ATMOSPHERE UPON GEYSERS.

In New Zealand, when the springs were first discovered, the natives frequently referred to the effect of the atmosphere upon the action of the geysers. One of them they called Tapui (wind pointer).

Capt. Gilbert Mair spent four years (1870–1874) taking observations in the Rotorua District. He notes that the springs are undoubtedly affected by the state of the atmosphere, and during the time mentioned above found no deviation.*

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*On the Influence of Atmospheric Changes on the Hot Springs and Geysers in the Rotorua District, by Capt. Gilbert Mair, New Zealand Trans. Inst., vol ix, 1876, pp. 22-29.

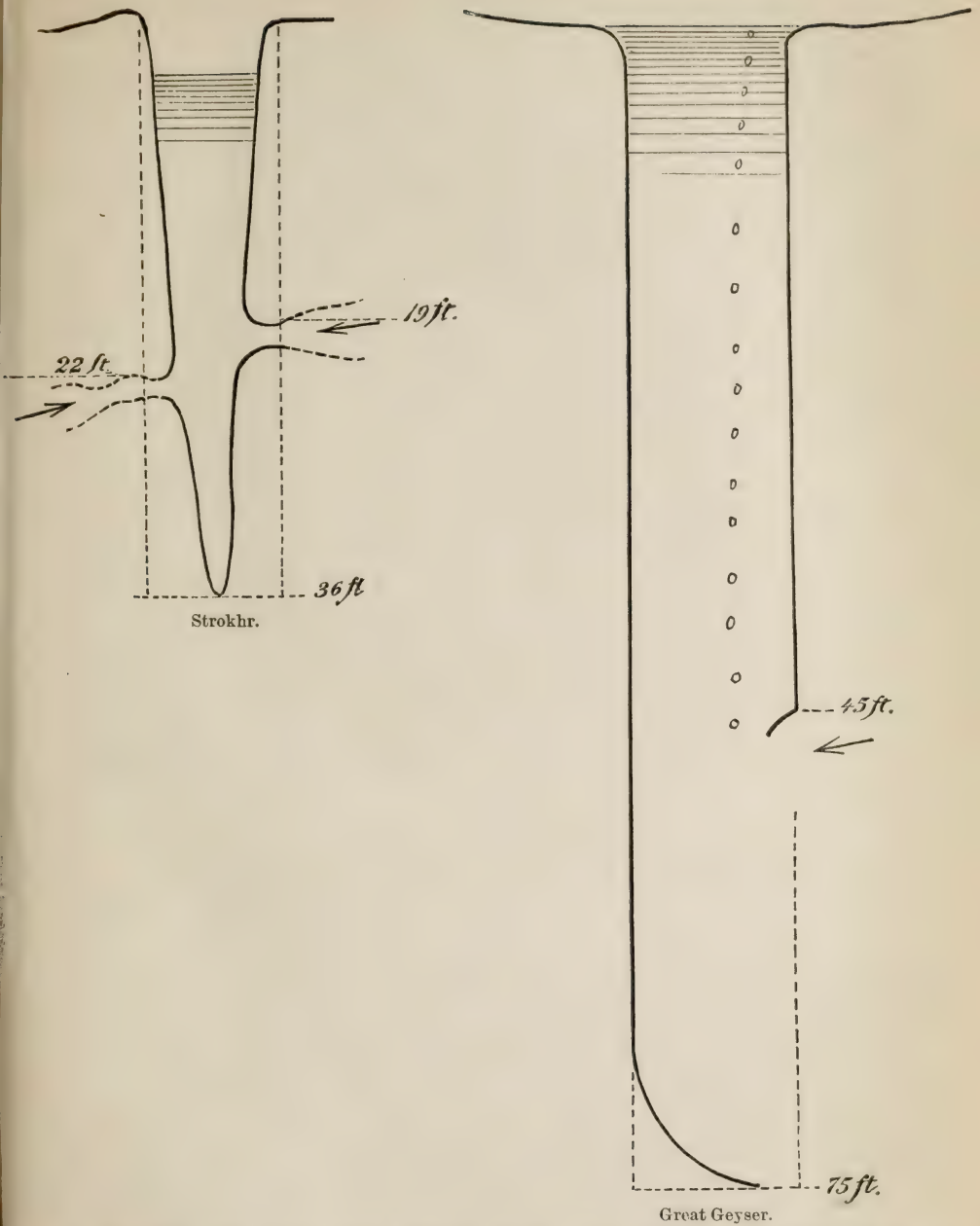

FIG. 32.—Sections of Strokhr and Great Geyser in Iceland (from Frost and Fire), showing two inlets to Strokhr and location of supposed inlet to the tube of the Great Geyser.

The following are some of his observations:

Tapui has a strong overflow when there are north and east winds, and the temperature then rises from 100° to 190°.

Springs at Whakarewarewa are very active during southwest and westerly winds.

Te Tarata, at Rotomahana, when there is a south wind the water recedes from the basin, and when the wind changes it refills.

Ketetahi, on the west slope of Tongarero, is active only during west winds.

In another spring he says that the water recedes in March or April to ten or fifteen feet and remains at blood heat until December, when there is an overflow and the temperature rises to 204° F. This agrees with the statement of Herbert Meade, who says that the Great Geyser at Waikite begins to rouse from a quiescent state about the 20th of December, and gradually increases in vigor until February, when it culminates and then gradually subsides.

In Iceland the eruptions of the Great Geyser are said to be finer after rain than at any other time. Data as to the atmospheric effect in Iceland is very meager.

In our own region we know absolutely nothing as to the effect of different seasons upon the geysers.

It is interesting in this connection to note that the inhabitants of Stromboli use the volcano as a weather-glass. A belief has prevailed from very early times that the eruptions of the vent depend upon the condition of the atmosphere. Judd thinks the opinion open to grave doubt, but says it is certain that more violent paroxysms occur during the winter than in the summer. Lyell says it must be admitted that earthquakes and volcanic eruptions in turn react upon the atmosphere, so that disturbances of the latter are generally the consequence rather than the forerunners of volcanic disturbances. Whether this is the case in the New Zealand geysers we cannot say, but it would appear that the effect of the atmosphere upon the geysers must be greater than their effect could possibly be upon the atmosphere.*

SYMPATHETIC OR SYNCHRONOUS ACTION.

Almost all observers of the geysers of the Yellowstone National Park have been inclined to regard the action of many geysers as sympathetic. This has been supposed to be the case in the springs and geysers of the Fountain Terrace in the Lower Fire Hole Basin, and on the platform of the Giant, and near the Turban in the Upper Fire Hole Basin. These facts have been detailed in Chapters VII and VIII, in Part I, and we there stated our opinion that the sympathy was only apparent, the synchronous action (or in some cases want of action) being only coincidences, for when we observed the same springs and geysers, the conditions were exactly the reverse of those noted by other observers. Certainly, at any rate, more extended observations are necessary to determine the fact as to whether the geysers situated in close contiguity are or are not in sympathy with each other. The same uncertainty on the subject is noted in respect to the Iceland geysers, some observers thinking them entirely independent of each other, while others believe that they are connected. That there are subterranean connections in the water supply may possibly be true, but that the action of one geyser is dependent upon the action of any of the others is, in our opinion, improbable in most cases. Some of the ideas presented by writers on

*In the coal mines explosions frequently follow sudden falls in atmospheric pressure.

this subject of sympathy remind us of Horrebow's statement as to the Great Geyser of Iceland. He says that if water from the geyser be put into a bottle, whenever the geyser has an eruption the water in the bottle will also be agitated, and if it be corked will burst.

GENERAL CONDITIONS NECESSARY FOR GEYSERS.

Before closing this chapter we will briefly recapitulate the general conditions that appear to be necessary to the existence of geysers. The special conditions are detailed in the preceding chapters.

1. The presence of igneous rocks which still retain their heat at a considerable distance below the surface. We have seen that if the heat at the surface is too great, stufas are the result, and that geysers are found where volcanic action is extinct or becoming dormant.

2. The presence of meteoric water which shall have access to the hot rocks which convert it into steam in part at least.

3. A *tube*, by means of which this heated water, with other meteoric water, can reach the surface and appear as a geyser.

Bunsen's idea was that the formation of a *siliceous* geyser tube was necessary, and that prior to the formation of this siliceous tube the spring was a simple thermal spring. The experiment demonstrating his theory proves the fallacy of this idea. In the Gibbon Geyser Basin also we have additional proof against this idea in the Steamboat Vent or Geyser, which has so recently begun the formation of geyserite that in 1878 it showed only as small points of deposit on surrounding rocks. Any tube will supply the necessary conduit to the surface, and we need not suppose that it is perfectly regular either in shape or size. The reverse is undoubtedly the condition in the majority of the geysers of the Yellowstone National Park.

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CONTENTS.

A.—Bibliography of the Yellowstone National Park
B.—Bibliography of Iceland hot springs and geysers
C.—Bibliography of the hot springs and geysers of New Zealand
D.—List of authorities for thermal springs of the United States
E.—List of authorities for thermal springs of Mexico, Central America, West Indies, and South America
F.—List of authorities for European thermal springs
G.—List of authorities for thermal springs of the Azores, Africa, and islands of the Indian Ocean
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I.—List of authorities for thermal springs of Japan, Formosa, Malaysia, Australia, and Polynesia
J.—List of authorities on the general subject of thermal springs
K.—List of authorities on "the color of water"

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MINERALOGICAL APPENDIX.

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A.—List of minerals of Yellowstone National Park.....
B.—Analyses of volcanic rocks from Yellowstone National Park .....

A.

LIST OF MINERALS OF YELLOWSTONE NATIONAL PARK.

By A. C. Peale, M. D.

Agate. (See *Quartz.*)
Alum. In springs of Hayden's Valley.
Amethyst. (See *Quartz.*)
Azurite (blue carbonate of copper). Near the head of Clarke's Fork of the Yellowstone River.
Amphibole. *Hornblende* in acicular crystals in rocks on the summit of Mount Washburne.
Calcite (carbonate of lime). *Rhomb spar*, in the valley of the Yellowstone, below mouth of Gardiner's River, associated with quartz and chalcedony; on East Fork of Yellowstone River, in geodes of agate; on bluff opposite Mammoth Hot Springs, on Gardiner's River; at Promontory Point, Yellowstone Lake.
Dogtooth spar (*crystals*), on volcanic rocks, near Mammoth Hot Springs.
Stalactites, in cave, at Mammoth Hot Springs.
Carnelian. (See *Quartz.*)
Calcareous tufa. (See *Travertine.*)
Chalcedony. (See *Quartz.*)
Chalcopyrite (copper pyrites). Clarke's Fork of Yellowstone River.
Chrysoprase. (See *Quartz.*)
Coal. A poor quality of lignite, opposite Mammoth Hot Springs, near Mount Hancock, on Hunter's River.
Feldspar. *Sanidine*, in various trachytes of the Park.
Flint. (See *Quartz.*)
Garnets. In gneissic rock, at Garnet Hill, near Elk Creek, in Junction Valley; in micaceous gneiss, on Blacktail-deer Creek; in Yellowstone Valley.
Galenite (sulphide of lead). Clarke's Fork of Yellowstone River.
Geyserite. (See *Opal.*)
Gypsum (sulphate of lime). *Selenite*, in the bluff opposite Mammoth Hot Springs of Gardiner's River; in old hot spring deposits opposite Tower Creek, on Yellowstone River.
Hydrophane. (See *Opal.*)
Halite (common salt). In small quantity in springs near Turbid Lake, east of Yellowstone Lake.
Hyalite. (See *Opal.*)
Hornblende. (See *Amphibole.*)
Jasper. (See *Quartz.*)
Malachite (green carbonate of copper). Clarke's Fork of Yellowstone River.
Obsidian (volcanic glass). In chips throughout the Yellowstone Valley, from the lower cañon to Yellowstone Lake.
Spherulitic, from Grand Cañon of Yellowstone River; at Obsidian Mountain, near Beaver Lake; and at numerous other points in the Park.
Porphyritic, from Grand Cañon of the Yellowstone; divide between Yellowstone and Madison Rivers; at Obsidian Mountain.

Opal. East Fork of Yellowstone River, Grand Cañon of Yellowstone.
Hydrophane, Grand Cañon of Yellowstone.
Wood opal, East Fork of Yellowstone River.
Hyalite, in the Grand Cañon of the Yellowstone; at the Gibbon Geyser Basin.
Pealite, at Gibbon Geyser Basin, where it is associated with Hyalite; near the Grand Geyser and Black Sand Geysers, in the Upper Fire Hole Basin; near the Union Geyser and Yellow Crater Spring, in the Shoshone Basin; on Witch Creek, in the Heart Lake Geyser Basin.
Geyserite (fierite or siliceous sinter). In the Geyser Basins of Fire Hole River, presenting white, gray, greenish, pink, and red varieties, massive, porous, filamentous, compact, cauliflower-like, beaded, or pearly. The specimens vary from translucent to opaque, some being very friable, while others are firm, even on drying; Hot Springs, on southwest arm of Yellowstone Lake; Geyser basin of Shoshone Lake, and Lewis Lake; in the Heart Lake Geyser Basin, on Witch Creek; in Hayden's Valley, and wherever siliceous hot springs are found in the Park.

Pealite. (See *Opal.*)

Plasma. (See *Quartz.*)

Prase. (See *Quartz.*)

Pyrite (iron pyrites). On Clarke's Fork of the Yellowstone River.

Quartz. *Rock-crystal*, in geodes, with chalcedony and calcite, from East Fork of Yellowstone River.
Amethystine (*amesthyst*), fine crystals in large geodes of chalcedony from East Fork of Yellowstone River, about ten miles above the junction of the Yellowstone. The specimens are found on the summit of a bold hill on the south side of the river.
Blue, near second cañon of the Yellowstone.
Milky, near second cañon of Yellowstone; East Fork of Yellowstone River.
Chalcedony, in chips throughout the Yellowstone Valley; in geodes with calcite and quartz, above second cañon in Yellowstone Valley; associated with jasper from Elk Creek, near Yellowstone River, Montana Territory; forming the outside of geodes from East Fork of Yellowstone River; also associated with calcite at same locality, from Grand Cañon of Yellowstone River; in rounded pebbles on shores of Yellowstone Lake.
Carnelian, from Grand Cañon of Yellowstone.
Chrysoprase, East Fork of Yellowstone River.
Prase, East Fork of Yellowstone.
Agate, in Yellowstone Valley, above second cañon; East Fork of Yellowstone River, near Elk Creek, Yellowstone Valley.
Flint (black variety), East Fork of Yellowstone River.
Jasper (red variety), Yellowstone Valley; back of East Fork of Yellowstone River; near Elk Creek; (yellow variety) East Fork of Yellowstone River; (gray variety) East Fork of Yellowstone; (green variety) East Fork of Yellowstone River; (black variety) East Fork of Yellowstone River.
Silicified wood, abundant throughout the valleys of Yellowstone, and in the Geyser Basins; on the southeast shore of Yellowstone Lake; handsome specimens are found on the East Fork of the Yellowstone River.

Sanidine. (See *Feldspar.*)

Selenite. (See *Gypsum.*)

Silicified wood. (See *Quartz.*)

Sulphur. In crystals at Mammoth Hot Springs of Gardiner's River; in the bluff on Yellowstone River, opposite Tower Falls; in mud springs at the foot of Mount Washburne; at Crater Hills, in Hayden's Valley; in small quantity in the Gibbon Geyser Basin and in the Lower Fire Hole Basin; in the Shoshone and Heart Lake Geyser Basins; on the divide between Yellowstone River and the East Branch of Fire Hole River.

Travertine (calcareous tufa). At the Mammoth Hot Springs of Gardiner's River; at Soda Butte, on the East Fork of Yellowstone River.

Viandite. In the various Geyser Basins of the Park.

Wood opal. (See *Opal.*)

B.

ANALYSES OF VOLCANIC ROCKS FROM YELLOWSTONE NATIONAL PARK.

By William Beam, A. B.

No. 1. Spherulitic obsidian. Collected by A. C. Peale, M. D.

From the divide between Yellowstone Lake and Upper Geyser Basin of Fire Hole River.

Greenish-black masses, transparent in thin pieces. Hardness, 6; specific gravity, 2.4; fracture, conchoidal. Pyrology: Fusibility, 4. Heated strongly, it swells up to a white blebby mass; with borax, gives a clear bead, and with microcosmic salt, a skeleton of silica.

COMPOSITION.

	Per cent.
SiO_2	77.00
$Al_2O_3 + Fe_2O_3$	13.40
CaO	1.25
MgO	1.19
K_2O	3.62
Na_2O	3.43
H_2O (by ignition)	.70
	100.59

No. 2. A pebble of Quartz-trachyte, covered with a deposit from Echinus Geyser. Collected by A. C. Peale, M. D.

A pebble about 1½ inches in diameter, light fawn color, and containing particles of clear silica. Texture, porous; rather friable; fracture, uneven; hardness, 3.5; specific gravity, 2.36. Pyrology: Nearly infusible; makes a clear bead with borax, and with microcosmic salt, leaves a skeleton of silica. The powdered mineral is slightly acted upon by hydrochloric acid.

ANALYSIS.

	Per cent.
SiO_2	77.90
$Al_2O_3 + Fe_2O_3$	14.55
CaO	.40
MgO	Trace.
K_2O	4.63
Na_2O	2.10
H_2O (by ignition)	1.00
	100.58

The film of deposit from Echinus Geyser is about one-eighth of an inch thick and the interior of the pebble has probably undergone some change in composition by the soaking of water into its substance.

No. 3. Rock from Yellowstone Cañon near falls. Collected by W. H. Holmes.

Consists of white opaque fragments, rough to the touch; fracture, conchoidal, rough; texture, porous. Pyrology: Fusibility, 5.5; dissolves in borax to a clear bead, and gives a skeleton of silica with microcosmic salt. Moistened with cobalt nitrate and heated, it turns bright blue. The powdered mineral yields 14.6 per cent. of its weight to hydrochloric acid.

ANALYSIS.

	Per cent.
SiO_2	64.60
$Al_2O_3 + Fe_2O_3$	25.65
MgO	Trace.
CaO	Trace.
K_2O	0.76
Na_2O	0.43
H_2O (by ignition)	8.70
	100.14

This rock has the appearance and qualities of a very compact or baked clay. It adheres strongly to the tongue, when breathed upon has a distinct pipe-clay odor, and the powder yields a plastic mass with water. Not being familiar with this region, I am unable to give a full explanation of the character of this rock, but I incline to the view that it is a clay metamorphosed by proximity to a dike or lava stream. The specimens examined may have been taken at some distance from the source of heat, as it seems difficult to suppose that a clay would retain its plasticity after having been heated to the degree that immediate contact with the melted rock would cause.

No. 4. Trachyte from Junction Valley. Collected by W. H. Holmes.

The pieces are greenish blue, interspersed with white and dark spots, and particles of free quartz. Slightly porous. Fracture, uneven. Hardness, 4.5; specific gravity, 2.84. Pyrology: Fusibility, 5.5; with borax gives reaction for iron; moistened with cobalt nitrate and heated, the white part turns blue and the green part brown.

ANALYSIS.

	Per cent.
SiO_2	69.90
Al_2O_3	17.58
Fe_2O_3	2.41
CaO	Trace.
MgO	Trace.
K_2O	4.16
Na_2O	2.41
H_2O (by ignition)	3.65
	100.11

NOTE.—In those analyses in which the alumina and ferric oxide are included in the same determination, the quantity of ferric oxide was quite small.

VALLEY OF THE YELLOW STONE RIVER.
LOOKING SOUTH FROM THE FIRST CANON

GEOGRAPHICAL FIELDWORK OF THE YELLOWSTONE PARK DIVISION.

By Henry Gannett, E. M.

LETTER OF TRANSMITTAL.

Washington, D. C., *September* 26, 1881.

Sir: I have the honor to transmit herewith my report on the field-work of the Yellowstone Park Division, United States Geological Survey of the Territories, during the season of 1878.

Very respectfully yours,

HENRY GANNETT.

Dr. F. V. Hayden.

ITINERARY.

In accordance with instructions, the Yellowstone Park Division started for its field of labor on July 26, 1878, taking the field at Granger Station, Wyoming, on the Union Pacific Railroad.

At the outset the party comprised, besides myself, Dr. A. C. Peale, geologist; J. E. Mushbach and Russell West, assistant topographers; with two packers and a cook. After entering the field of work, Messrs. Peale and Mushbach were detached for special work in connection with the hot springs and geysers, while Mr. W. H. Holmes joined my party as geologist.

The route of the party to the field of work lay up the Green River Basin, following in a general way the course of Green River. At the mouth of Lead Creek we left the Green on our right and struck over in a northwesterly direction to the drainage basin of Hoback's River, a large left-hand branch of Snake River. This stream heads in the eastern slopes of the Wyoming Range, and in the southwestern slopes of the Gros Ventres Mountains, and, having accumulated its waters in a basin in the angle of these two ranges, it cuts a tremendous gorge through the former on its way to join the Snake. This cañon has been very much used by the Gros Ventres, Bannock, and Shoshone Indians as a

part of their route from the Snake River Plains to the Wind River Valley and the buffalo range, as the broad and deeply-cut trails testified. But for many years the route had been deserted, as we found large trees growing across the trails and completely obstructing them. The cañon is narrow, with precipitous walls, and in some places difficult and dangerous for pack-animals. I am inclined to believe that only war and hunting parties were in the habit of using it, as lodge-poles and the other bulky paraphernalia of an Indian village would find the passage through these defiles both difficult and dangerous in the extreme. It was through this cañon that Mr. Hunt and his companions made their way in 1811 to the banks of the Snake or "Mad" River, in their terrible journey to Astoria.

Hoback's River enters the Snake a few miles below the head of the cañon of the latter stream, but above its mouth the cañon is not at all difficult to traverse.

Turning northward, on reaching the Snake, my party followed up this stream through the broad valley known as Jackson's Hole, passed Jackson's Lake, at the head of the valley, and left the stream only at the point where the Lewis or Lake Fork joins it, at the southern boundary of the Yellowstone Park, where we arrived on August 9. Here the work began. At this point we turned westward, following up a small branch of Lewis Fork. This little stream, heading in springs at the base of Pitchstone Plateau, we left on our right, and, crossing a low divide, in a gap between the Teton Range and Pitchstone Plateau, we struck Falls River, here a good-sized stream. This river we followed down to the border of that great marshy valley known as Falls River Basin. We then skirted this valley to the point of debouchement of Bechler's Fork from the high plateau. Here we turned our backs upon Falls River Basin, climbed the plateau on the northwest side of Bechler's Fork, and followed its general course, keeping on the high plateau, near its cañon. Reaching its head, we struck over a low divide, and descended to the Shoshone Geyser Basin, on Shoshone Lake. This was on August 14. At this point I remained, detained by rainy weather, until the 21st, occupying myself in the intervals between the showers in surveying the Basin.

On the 20th I started, accompanied by a packer, on a trip to the Red Mountains for the prosecution of the topographical work in and about them, leaving the balance of the party at Shoshone Lake.

From the west end of Shoshone Lake I traveled on a direct course to the west end of the mountain group, then climbed the range at this end, and traveled along the crest to Mount Sheridan, being obliged to leave the top only once, and then for only a short distance.

On the 21st, while still in the mountains, I was joined by Mr. Holmes, and together we completed the trip, surveying the country in reach from the Red Mountains and Flat Mountain. Returning, we touched the northeast corner of Lewis Lake, crossed Lewis Fork at the outlet of Shoshone Lake, and thence skirted the latter around to camp.

Immediately after returning from this trip, on the 26th, my whole party went over to the Firehole River, and down it to the Upper Geyser Basin. Delaying there a day, we moved down to the Lower Basin, having left Messrs. Peale and Mushbach behind to carry on their work. While on this march we learned for the first time that the hostile Bannocks were in our vicinity. As the reports were very indefinite as to the extent of the danger, we decided to remain where we were until more information should reach us. Meanwhile we located our camp in

a defensible position, corraled our stock at night, and took other precautions customary under similar circumstances. As usual, definite information diminished the danger very much, and after two or three days' delay we went on. Crossing to the Yellowstone by Howard's road, we stopped two days at the Falls, then drove on down the river, and reached the Mammoth Springs, where our supplies were stored, on September 7. From that date to the 12th we were busied about that place, visiting, among other points, Sepulchre Mountain and Electric Peak.

On the 12th we started again, returning up the Yellowstone to Baronette's bridge, where we crossed it, and followed up the East Fork to a point above the mouth of Soda Butte Creek. Then leaving it, we crossed to Pelican Creek, by which and Turbid Creek we reached Yellowstone Lake. Then we followed the lake up to the head, and went several miles up the Upper Yellowstone. Returning, we followed the lake shore around to the head of the river, and thence followed the river trail down to the Mammoth Springs, reaching them on October 2.

Having refitted, we started again, this time up the Norris road, to survey the drainage areas of Gardiner's and Gibbon Rivers. We traveled up the wagon road nearly to the head of the cañon of the Gibbon, which enabled me to connect with the work done in that neighborhood earlier in the season. Then we skirted the east base of the Gallatin Range, making stations on the summits; and then, the season being far advanced, the weather being very bad, and the snow rapidly becoming deeper, I judged it best to close the work, although the whole plan had not been carried out.

We arrived finally at the Mammoth Springs on October 11, and at Bozeman, where the party disbanded, on the 16th. The whole distance traveled by my party is estimated at 830 miles. In the prosecution of my work I traveled an estimated distance of 1,250 miles.

GEOGRAPHICAL WORK.

The area assigned to me for survey during the field season of 1878 was the Yellowstone National Park, situated mainly in northwestern Wyoming, though embracing narrow strips of Idaho and Montana. The area is 3,312 square miles.

While a part of this region had been surveyed by the meander method, in 1871 and 1872, by this organization, still there were large gaps in the maps; while, in addition, the whole work required correction by the introduction of a system of triangulation. Many reconnoissances of the Park have been made, the War Department having sent no less than four distinct expeditions (of which more hereafter), but all have traversed very nearly the same routes, so that the map of any one of them is very like those of the others, differing only in matters of detail or of longitude. For this reason I have used only the earlier maps of this organization, in so far as I have used any other work than my own, in making up the general map; as I had found, experimentally, that the work of Schönborn and of Bechler was at least as good as any other which had been done in the region, and covered all the country which any of the others do.

Within the Park Mr. Wilson located three primary points—Electric Peak and Mounts Washburn and Sheridan. Starting from these, I established a large number of secondary points, distributed over the Park to as good advantage as the topographical conditions would ad-

mit, sketching the topography and correcting it by locations in the usual manner.

Owing to delays, caused by the neighborhood of hostile Indians, and by bad weather, I was unable to complete the area assigned me. The unfinished portion is in several parts, distributed about the western, southern, and eastern borders, the larger part being on the west. Altogether, possibly 500 square miles remain undone.

The general map of the Park has been plotted on a scale of one mile to an inch, and published on half that scale, *i. e.*, two miles to an inch. The contours are approximately 100 feet apart, vertically.

During the season one of my assistants, Mr. J. E. Mushbach, was employed in making minute and detailed surveys of the most important groups of springs. From his notes I have made maps of the following groups:

Name of group.	Scale of plot.	Scale of published map.
	Feet per inch.	*Feet per inch.*
Upper Geyser Basin	400	500
Lower Geyser Basin	500	800
Gibbon Geyser Basin	200	400
Mammoth Hot Springs	250	400
Shoshone Geyser Basin	100	500
Witch Creek Group	500	1600
Egeria Springs	200	266
Rustic Geyser Group		100

Heights have been determined, as usual, by the cistern barometer, in connection with the vertical circle of the theodolite. Aneroids have been used very little and with the greatest caution, as they have been found to be extremely untrustworthy.

Barometrical observations have been referred, for computation of heights, to those of the United States Signal Service, at Virginia City, Mont. The height of this station was determined by the computation of a year's coincident observations at this point and Salt Lake City, Utah, giving, as a mean result for the former station, a height above Salt Lake City of 1,533 feet. The height of the barometer at Salt Lake City was determined as follows:

	Elevation in feet.
Ogden track Union Pacific and Central Pacific Railroads, Gardner*	4,303
Salt Lake City track, below Ogden track, by the Utah Central Railroad	42
Salt Lake City track, above sea	4,261
Signal office, Salt Lake City, cistern of barometer, above track, from levels by United States Signal Service	93
Signal office, Salt Lake City, cistern of barometer, above sea	4,354
Hence, Virginia City, signal service office, 1878, above sea	5,887

The sub-party, under Dr. Peale, was stationary for considerable periods, and, as a full barometrical record was kept by Mr. Mushbach, of that party, I have considered it best to treat the camps of that party as subsidiary hypsometric bases, determining their heights directly from Virginia City, and then using them for the determination of the heights of my more transient camps and stations. The heights of these subsidiary bases were determined from observations extending over intervals from one to three weeks, an interval long enough, particularly as they were quite near Virginia City in height, to establish their elevations with an approach to accuracy. Now, as all these bases are within the small area of the Park, heights determined from them can be sub-

*Annual Report U. S. Geol. Survey, 1873, p. 658.

ject to but very small errors of gradient. That the results are as good as could be expected from barometric work, the following table, comparing measurements made in 1878 and in 1872, when the conditions were not as favorable, will show:

	1872.	1878.
	Feet.	*Feet.*
Electric Peak, west summit	10,997	11,100
Mount Washburn	10,388	10,346
Camp on Elk Creek	6,236	6,436
Camp at Mud Geysers	7,712	7,725
Yellowstone Lake	7,788	7,738
Camp in Lower Geyser Basin	7,252	7,236
Shoshone Lake	7,870	7,830
Lewis Lake	7,757	7,800
Red Mountain	9,806	9,777
Mount Sheridan	10,343	10,385
Forks of Snake River	6,892	6,786
North Twin Butte	7,962	7,976

These discrepancies, which, to one accustomed to deal only with results by level, would appear enormous, are, in reality, quite within the range of ordinary barometric work in a mountainous region. Discrepancies of 200 feet between single results are not unfrequently met with, and a close accordance among three, four, or five results is a most rare accident, and suggests to one acquainted with such work anything but great accuracy in manipulation and computation. The best barometrical observer finds it impossible to set and read his instrument with certainty closer than .006 or .008 of an inch. Add to this the defects in the barometric formula and constants, which produce periodic errors of great magnitude, and which, though they can be to some extent avoided, cannot be wholly eliminated, and the great accidental errors arising from differences in barometric gradient, and it is easy to see that the barometer has no claims and can have none to being an accurate instrument. All that can be claimed is that, when used to the best possible advantage, it will give results approximating to the truth. To illustrate the range of results given by this instrument, I add, in the following lists, the measurements of a few points in the region under consideration, as made by several different observers, at different times and under different conditions.

The measurements made by Dr. Hayden's first expedition, in 1871, were made with the siphon barometer, and were computed by the aid of an assumed base of 30 inches for the barometer at the sea-level. The discrepancies between these results and my own, amounting, in some cases, to several hundreds of feet, are due to the faulty method of computation, as I demonstrated in my report on the work of 1872.

The large differences between my own results and those of Captain Jones, which, as will be noticed, average about 200 feet, and are quite constant, his results being the lowest, are not as easily accounted for. But as my results during the two years 1872 and 1878 are, within fair limits of error, the same, and as they remain the same, whether computed from Virginia City, from Salt Lake City directly, or from Cheyenne, I cannot believe that I have a constant error. Moreover, the results of Messrs. F. A. Clark, George B. Chittenden, and G. R. Bechler, who have, under this organization, during the past two years, carried on topographical surveys embracing parts of the region traversed by Captain Jones, show the same discrepancies between elevations of points determined by them and by Captain Jones. It seems fair to assume, therefore, that the burden of proof lies with the latter.

MOUNTAINS.

Names.	Range.	Latitude.	Longitude.	Elevation.
		° ′ ″	° ′ ″	*Feet.*
Mount Hancock		44 09 00	110 25 00	10,235
Mount Sheridan	Red Mountains	16 00	32 00	10,385
Mount Sheridan (Hayden, 1872)	do			10,343
Mount Sheridan (Jones, 1873)	do			10,150
Red Mountain	do	17 30	32 20	9,777
Red Mountain (Hayden, 1872)	do			9,806
3–9	do	16 00	32 20	10,320
4–9	do	16 10	32 40	10,305
5–9	do	17 10	32 50	9,742
7–9	do	16 10	33 00	10,200
8–9	do	16 00	33 30	10,144
9–9	do	15 50	33 40	10,104
10–9	do	15 10	33 30	9,698
3–13	do	16 30	34 40	9,448
26–8	do	16 20	34 50	9,627
27–8	do	16 00	35 00	9,690
Station 8	do	15 50	35 40	9,560
Mount Washburn	Washburn Mountains	48 00	26 20	10,346
Mount Washburn (Hayden, 1872)	do			10,388
Mount Washburn (Jones, 1873)	do			10,105
Station 20	do	47 30	23 50	9,692
Station 18	do	46 25	32 30	9,494
40–19	do	53 30	31 30	9,166
41–19	do	51 30	35 00	9,794
42–19	do	51 30	36 25	9,638
43–19	do	50 40	34 50	9,855
13–18	do	53 30	30 30	9,633
14–18	do	52 10	32 50	9,468
20–18	do	51 50	34 00	9,503
37–19	do	48 30	26 20	9,711
11–18	do	48 00	30 00	9,894
12–18	do	47 00	30 20	9,809
44–19	do	47 00	33 40	9,432
Dunraven Peak	do	47 00	28 30	9,988
12–19	do	47 10	27 00	9,506
13–19	do	47 30	26 30	10,001
14–19	do	47 35	26 20	10,122
15–19	do	47 50	26 00	10,270
c–20	do	47 40	25 30	9,935
Electric Peak	Gallatin Range	45 00 30	50 30	11,155
West Electric Peak	do	0 30	51 00	11,100
West Electric Peak (Hayden, 1872)	do			10,992
Sepulchre Mountain, station 25	do	44 59 40	46 00	9,737
Sepulchre Mountain, station 26	do	59 25	46 20	9,769
Cinnabar Mountain	do			7,343
Bunsen Peak	do	56 00	42 40	8,775
8–25	do	59 40	52 20	10,282
7–25	do	59 30	53 00	10,292
6–25	do	59 25	53 00	10,253
5–25	do	58 40	52 50	10,236
4–25	do	57 45	53 10	10,626
3–25	do	56 50	52 30	10,433
2–25	do	56 50	53 50	10,478
1–25	do	57 15	51 40	10,060
19–25	do	57 20	52 00	10,153
25–22	do	54 30	49 30	10,026
Quadrant Mountain	do	54 50	50 00	10,127
5–46	do	52 10	51 00	10,142
4–46	do	49 25	53 00	9,800
3–46	do	52 15	51 00	10,150
2–46	do	52 25	50 25	10,074
1–46	do	49 15	50 45	10,200
11–47	do	53 10	51 15	10,358
12–47	do	50 50	53 30	10,173
Left Madison Mountain	do	48 50	52 30	9,868
Mount Holmes	do	49 20	51 35	10,528
10–47	do			10,240
14–47	do			10,128
7–46	do	50 25	52 25	10,075
1–*d*	do	47 30	51 20	9,150
Mount Evarts	do			7,600
Emigrant Peak (*d*)	Yellowstone Range			11,034
26–25	do			10,720
Hell Roaring Mountain	do	45 00 20	26 50	8,418
1–21	do	1 20	25 15	8,040
14–21	do	1 00	25 00	8,012
Station 31	do	44 56 50	16 30	7,788
Bison Peak	do	56 50	13 25	9,038
1–30	do	57 45	9 50	9,927
2–30	do	45 00 25	6 00	10,726
3–30	do	1 00	7 00	10,364
4–30	do			9,862
2–31	do			8,906
Soda Hill	do	44 54 20	11 00	9,518

MOUNTAINS—Continued.

Names.	Range.	Latitude.	Longitude.	Elevation.
		° ′ ″	° ′ ″	*Feet.*
Index Peak	do			11,702
Baronette's Peak	do	58 30	5 00	10,459
2-33	do	54 00	4 20	10,529
3-33	do	53 30	4 40	10,332
4-33	do	53 00	5 20	10,025
Mount Norris	do	52 40	5 30	10,019
White Cañon	do	55 10	9 15	9,866
Outer Point	do	54 30	9 50	9,506
Specimen Ridge (top)	do	52 10	17 00	8,806
Station 34	do	51 10	13 30	8,703
Amethyst Mountain	do	49 40	15 00	9,423
10-36	do	48 00	2 30	9,054
Station 37	do	51 30	8 30	8,277
1-*a*	do			10,576
2-*a*	do			10,460
3-*a*	do	42 30	0 50	10,132
4-*a*	do			11,000
5-*a*	do			10,874
6-*a*	do			10,735
7-*a*	do			10,873
8-*a*	do			11,062
12-*a*	do	39 40	5 30	9,570
14-*a*	do	39 00	6 40	9,307
15-*a*	do	38 30	7 20	9,346
16-*a*	do			10,678
17-*a*	do	35 20	6 20	10,820
18-*a*	do	34 30	6 00	10,624
19-*a*	do	34 20	6 45	10,500
Pelican Hill	do	39 00	11 35	9,580
2-38	do	33 25	8 00	10,374
Mount Chittenden	do	32 50	10 30	10,190
Mount Chittenden (Jones, 1873)	do			10,027
Lake Butte	do	30 50	15 45	8,822
2-39	do	32 30	10 20	10,108
2-39 (Jones, 1873)	do			9,938
13-39	do	30 40	8 45	10,137
14-39	do	29 30	8 40	10,434
15-39	do	29 20	9 00	10,478
7-39	do			10,624
8-39	do			10,474
3-39	do	31 40	10 00	10,142
Grizzly Mountain	do	28 10	10 40	9,982
4-42	do	27 30	10 00	9,964
Smoothface Mountain, north	do	28 40	7 50	10,500
Smoothface Mountain, south	do	28 30	7 45	10,417
Station 43	do	25 30	13 40	9,078
Signal Hill	do	25 00	16 30	8,210
3-42	do	27 20	8 40	10,252
Mount Doane	do	24 45	9 00	10,713
Mount Stevenson	do	24 00	9 45	10,420
Mount Langford	do	24 25	6 30	10,779
20-44	do	23 25	4 15	10,902
22-44	do	22 40	4 10	11,155
20-41	do	23 10	11 00	9,815
21-41	do	22 25	11 30	9,704
22-41	do	21 50	11 50	9,730
20-44	do	23 15	8 00	10,507
19-44	do	22 00	8 25	10,122
Turret	do	16 15	4 05	11,142
23-44	do	18 50	6 25	10,706
24-44	do	18 40	7 35	10,389
25-44	do	17 30	6 45	10,884
26-44	do	17 50	7 00	10,919
27-44	do	17 40	8 05	9,939
28-44	do	17 20	8 40	9,519
40-44	do	13 00	3 10	10,680
17-9	Continental Divide, south of Yellowstone Lake.	15 10	23 40	9,300
19-9	do	13 00	24 25	9,700
20-9	do	11 20	23 30	9,600
Flat Mountain		21 20	26 20	9,200
Promontory Top		22 00	17 00	8,706
Elephant's Back				8,884
Garnet Hill		57 10	26 10	7,177
South Twin Butte, Lower Geyser		32 00	53 10	7,977
South Twin Butte, Lower Basin (Hayden, 1872).				7,979
North Twin Butte, Lower Basin		32 30	52 50	7,976
North Twin Butte, Lower Basin (Hayden, 1872).				7,962
Sphinx	Madison Range			10,700
Lone Mountain	do			11,186
Station 16 (high ridge north of Gibbon's Fork).		39 40	51 45	8,520

ELEVATIONS OF MISCELLANEOUS POINTS.

	Feet.
Amethyst Creek, trail crossing of	6,703
Baronette's bridge (Hayden, 1872)	5,978
Beaver Lake	7,415
Bechler's Fork, head of Fall River Basin	6,411
Bechler's Fork, at head of stream	8,191
Bechler's Fork, butte in forks of	8,451
Beulah Lake (Hayden, 1872)	7,530
Blacktail Deer Creek, crossing of lower trail	6,570
Cascade Creek, camping ground on (Hayden, 1872)	7,912
Cascade Creek, camping ground on (Jones, 1873)	7.724
Crater Hills	7,820
Divide:	
Firehole, Snake, and Henry's Fork (Hayden, 1872)	8,761
Lewis Lake to Yellowstone Lake (Hayden, 1872)	8,024
East Fork of Firehole to Yellowstone River (Hayden, 1872)	8,893
Lower Geyser Basin to Henry's Fork (Hayden, 1872)	8,267
Yellowstone to East Fork of Firehole (Hayden, 1872)	8,164
East Fork of Gardiner's River to Blacktail Deer Creek	6,887
Gardiner's River to Gibbon River	7,760
Pelican Creek to East Fork of Yellowstone	8,600
Broad Creek to East Fork of Yellowstone	8,822
Agate Creek to East Fork of Yellowstone	9,061
Firehole to Shoshone Lake, northeast corner	8,523
Shoshone Creek to Firehole River	8,245
Shoshone Geyser Basin to Bechler's Fork	8,677
Madison Lake to Bechler's Fork	8,504
East Fork Firehole to Yellowstone, on Howard Road	8,336
Snake to Falls River	7,434
East Fork of Firehole:	
Mouth of (Hayden, 1872)	7,237
At the base of the divide	7,460
East Fork, Gardiner's River:	
Foot of Gates	6,387
Top of Gates	6,587
At bend	6,850
Where the trail leaves it	6,887
East Fork of Yellowstone River:	
Mouth of	5,970
Mouth Soda Butte Creek	6,700
Elk Creek:	
Camping ground	6,436
Camping ground (Hayden, 1872)	6,236
Summit above	7,476
Falls River:	
At head Falls River Basin	6,478
Plateau east of	7,568
Flat-topped butte, in Forks of Yellowstone	6,610
Gardiner's River:	
Mouth of (Hayden, 1872)	5,360
Forks of	6,200
Geode Creek, crossing of, on trail	7,362
Gibbon Lake	7,838
Gibbon River:	
Mouth of (Hayden, 1872)	6,811
Head of cañon of	7,350
Gibbon Geyser Basin	7,527
Heart Lake	7,475
Heart Lake, Geyser Basin	7,475
Hering Lake	7,530
Holmes, Mount, base of	7,885
Indian Creek:	
Mouth of	7,246
At base of Gallatin Range	7,643
Lewis Lake	7,800
Lewis Lake (Hayden, 1872)	7,757
Lower Geyser Basin	7,236
(Hayden, 1872)	7,252
(Jones, 1873, higher point)	7,162

	Feet.
Madison Lake (Hayden, 1872)	8,300
Madison River, at foot of cañon	6,605
Mammoth Hot Springs:	
At cabins	6,387
Summit above, on Norris road	7,310
Mary's Lake	8,336
Mud Geysers on Yellowstone River	7,725
Mud Geysers on Yellowstone River (Hayden, 1872)	7,712
Quadrant, Mount, base of	7,718
Riddle Lake	8,000
Salt Lake City, United States signal office [b]	4,354
Shoshone Geyser Basin	7,837
Shoshone Geyser Basin (Hayden, 1872)	7,881
Shoshone Lake	7,830
Soda Butte Creek, mouth of	6,700
Snake River, Forks of	6,786
Snake River, Forks of (Hayden, 1872)	6,892
Sulphur Springs, near Mary's Lake (Hayden, 1872)	8,246
Tower Creek:	
Mouth of	6,207
Trail crossing of	6,579
Upper Geyser Basin:	
Near Old Faithful	7,372
Near Castle	7,377
Near Castle (Hayden, 1872)	7,394
Near foot of basin (Jones, 1873)	7,373
Upper Geyser Basin, east wall of	7,645
Virginia City, Mont., United States signal office [c]	5,887
Washburn Group, Pass in, over which trail passes	8,867
West Fork Gardiner's River, head of valley on	7,300
Witch Creek, foot Red Mountains	8,310
Yellowstone Lake	7,738
(Hayden, 1872)	7,788
(Jones, 1873)	7,564
Yellowstone River:	
At Mud Geysers	7,705
Top Upper Falls	7,693
Bottom Upper Falls	7,581
Top Lower Falls	7,575
Bottom Lower Falls	7,275
Yellowstone Cañon, east side, top of, at falls	7,710
Yellowstone River:	
Mouth Tower Creek (Hayden, 1872)	6,207
Mouth East Fork (Hayden, 1872)	5,970
Mouth Gardiner's River (Hayden, 1872)	5,360

LATITUDES AND LONGITUDES OF MISCELLANEOUS POINTS.

Locality.	Latitude.	Longitude.
	° ′ ″	° ′ ″
North boundary of Park	45 01 45	
East boundary of Park		110 00 00
South boundary of Park	44 08 00	
West boundary of Park		111 06 00
Mouth of Gardiner's River	45 01 45	110 42 20
Mouth of East Fork of Yellowstone River	44 55 40	24 00
Mouth of Soda Butte Creek	52 10	11 30
Outlet of Yellowstone Lake	34 00	23 00
Mouth of Upper Yellowstone	18 30	13 00
Mouth of Barlow's Fork	7 30	31 30
Outlet of Heart Lake	15 00	27 40
Forks of Snake River	8 30	41 00
Outlet of Shoshone Lake	21 20	40 00
Outlet of Lewis Lake	16 45	38 00
Mouth of East Fork of Firehole River	35 00	50 10
Mouth of Gibbon River	38 30	52 00

HISTORY OF EXPLORATIONS IN THIS REGION.

The first authentic information regarding the great natural wonders of the Park was derived from a prospecting party under the leadership of Capt. W. W. De Lacy, who in 1863 visited the Lower Geyser Basin. Previous to this time it seems that the region was known to but a few hunters and trappers, and their tales were treated as the wildest of romancing, as, indeed, many of them were, the mind of the trapper being singularly prone to exaggeration. The earliest reference to the hot springs with which I am acquainted is in the stories of a trapper by the name of Colter (or Coulter), who accompanied Lewis and Clarke's celebrated expedition across the continent. On the return of this expedition, when below the mouth of the Yellowstone, Colter was discharged, at his own request, and immediately returned to the country above the forks of the Missouri. In this neighborhood, probably on the Jefferson, his companion, Potts, was killed by Blackfeet, and he was captured. Almost miraculously he escaped from them, and, entirely naked, made his way to a trading post on the Bighorn. After this he lived for a year or more among the Bannocks, whose range included what is now the Yellowstone Park. Either during his perilous journey after his escape from the Blackfeet or during his sojourn among the Bannocks he became acquainted with the region of the hot springs and geysers, for we find him in Missouri in 1810, telling marvellous tales of lakes of burning pitch, of land on fire, hot springs, and geysers. His stories were of course treated as travelers' tales, and "Colter's Hell" was classed with Lilliput, Symmes's Hole, and other inventions of over-developed imaginations.

Later we find the knowledge of this country more generally diffused among this people. Colonel Raynolds, in his report on the "Exploration of the Yellowstone," in 1859–'60, refers to "some of these Munchausen tales" as follows (p. 77):

> One was to this effect: In many parts of the country petrifactions and fossils are very numerous, and as a consequence it was claimed that in some locality (I was not able to fix it definitely) a large tract of sage is perfectly petrified, with all the leaves and branches in perfect condition, the general appearance of the plain being *unlike* (like?) that of the rest of the country; *but all is stone;* while the rabbits, sage hens, and other animals usually found in such localities are still there, perfectly petrified, and as natural as when they were living; and, more wonderful still, the petrified bushes bear the most wonderful fruit; diamonds, rubies, sapphires, emeralds, etc., etc., as large as black walnuts, are found in abundance.

This story, absurd as it sounds, has a large basis in fact. The narrator, however, had mixed up distinct phenomena, and over all had spread lavishly the coloring of his imagination. There are fields of sage, as well as bits of forest, which, lying in immediate proximity to groups of springs, have been petrified while standing. The hot silicious water from the springs is drawn up through the pores of the wood, and between the wood and the bark, by capillary attraction, and, depositing silica wherever it goes, the tree or bush is rapidly transformed into rock.

The story of the remarkable fruit borne by these stone trees is not far from correct, the main difference between the story and the fact being that the fruit is borne on the outside and inside of the trunks of the trees, instead of on the ends of the branches. The mineral species are not as given in the story, either, but that is a matter of no vital importance. In the process of silicification of wood the last result of all is the production of quartz crystals. The tree trunk is converted totally into crystalline quartz, radiating from within outwards, the crystals being all crowded out of shape. The inside and outside of the hollow cylinder

of quartz which represents the former tree are covered with the characteristic quartz pyramids. Such products of silification are very abundant in the Park, particularly on Amethyst Ridge, and are undoubtedly the "stone fruit" of the petrified trees and bushes. The crystals are colorless, amethystine, or yellow, and according to the color are known to the mountain man as diamond, amethyst, topaz, &c.

It is unnecessary to say that the part of the story relating to animal life was manufactured from whole cloth.

The other story, in its main fact, is undoubtedly true. Many streams which at their heads are icy cold become lower down in their courses warm, or even hot. Bridger, however, attempted to account for this phenomenon without an adequate knowledge of the facts in the case. The cause of the heating of the water was not friction, due to its rapid descent, but the large accessions of hot water from springs situated along its course.

Many other similar legends had long been current among mountain men, some of which are briefly referred to in Colonel Norris's report to the Secretary of the Interior for 1878, but none of them seem to have attracted any attention. That white men have been in the Park prior to any printed record is evidenced by the discovery by Colonel Norris, as noted in his report above referred to, of a block-house near the Grand Cañon, of a caché of marten traps near Obsidian Cañon, and other relics of the early trappers.

In Mullan's "Military Road Report," 1863, pp. 19 and 53, mention is made of hot springs and geysers at the head of the Yellowstone, as if they were well known at that time.

In 1863 Capt. W. W. De Lacy, in command of a large party of prospectors, left Montana to prospect on the upper waters of the Snake. Striking that river near the junction of Henry's Fork, they followed up the main river through the cañon, prospected in Jackson's Hole, and not finding gold in paying quantities they broke up the party, some returning one way, some another. Captain De Lacy, with a portion of the party, followed up the Snake and Lewis Fork, discovering Lewis and Shoshone (De Lacy's) Lakes, the Shoshone and the Lower Geyser Basins.

Mention of this trip was made in Raymond's Report on Mineral Resources for 1869, and in 1876 the narrative was published in full in "Contributions of the Historical Society of Montana."

The geographical work done by Captain De Lacy on this trip was embodied in a map of Montana, drawn by him and published by authority of the Territory in 1864–'65, and the material thus made public was afterward used by the public land office and the Messrs. Colton, of New York, in the compilation of maps of that region.

The results of this trip, however, seem to have attracted little or no attention, for we hear of no one going into the country until 1869, when two prospectors, Cook and Folsom, made a prospecting tour through the Park. They followed the Yellowstone up to the mouth of the East Fork, then up the latter stream for a few miles, crossing over to the Yellowstone at the Great Falls; thence they went up this stream to the foot of the lake and around the west side of the latter to the extremity of the west arm, thence crossing over to the Geyser Basins on the Madison, and finally left the country by following down the Madison River. Their story immediately attracted attention, and the following summer a large party, composed of citizens of Montana, under the leadership of General Washburn, then surveyor-general of Montana, was

made up for the purpose of exploring this region. A small escort from Fort Ellis, in charge of Lieut. G. C. Doane, accompanied them.

This party made quite extensive explorations on the Yellowstone and Madison Rivers. Passing up the Yellowstone by the well-known trail, they travelled completely around the lake, visiting all localities of interest along the route, with the single exception of the Mammoth Hot Springs on Gardiner's River. While near the head of the lake, Mr. Evarts, a member of the party, became separated from the others and completely lost. After suffering untold hardships from hunger and cold, rendering him temporarily insane, this gentleman was at last found near the Mammoth Hot Springs.

The story of this expedition was graphically told by Mr. N. P. Langford, one of the members of the party, in the pages of Scribner's Monthly Magazine; while Lieutenant Doane, commanding the escort, furnished a brief report accompanied by a map of the route. The following year, 1871, Captains Barlow and Heep, U. S. A., made a reconnaissance of this country, and presented the results in a brief report and a map of their route.

In the same year Dr. Hayden devoted a portion of the season to a reconnaissance of this region, making quite an extended tour through it. The results of this work, including geological reports, maps, &c., were published in the annual report for that year. This was sufficient to fix the public attention upon this great collection of natural wonders, and when Dr. Hayden presented to Congress a proposition to reserve this section from settlement as a National Park it was adopted with little opposition.

The following year, 1872, Dr. Hayden continued the reconnaissance of the Park and the country to the north and south of it, publishing the results in the report of that year, and in a series of maps.

This region has, ever since its discovery, proved an attractive field for exploration, and scarcely a year has passed that some party, under more or less of official sanction, has not traversed it, nominally at least, for purposes of exploration.

In 1873 Capt. W. A. Jones, U. S. A., took a large party through it. He entered it from the head of the Stinking Water, crossing one of the many passes near Mount Chittenden (it is impossible to tell which). After visiting most of the points of interest in the Park he went out via the Upper Yellowstone, on the way verifying the old trappers' legend about the "Two Ocean River," and discovering a practicable pass (Togwotee Pass) and route from the south to the Park. This discovery was by far the most valuable result of the expedition.

In 1875 Capt. William Ludlow, U. S. A., in charge of a reconnaissance in Central Montana, made a flying trip to the Park. He developed little that was new save accurate measurements of the Upper and Lower Falls of the Yellowstone, quoted elsewhere.

YELLOWSTONE NATIONAL PARK.

BOUNDARIES.

According to the law by which the Yellowstone National Park was created, its boundaries were established as follows: The northern boundary is on the parallel which passes through the mouth of Gardiner's River. This point, which I have established as accurately as possible, is just 2 miles north of the parallel of 45° north latitude, which is the northern boundary of Wyoming. The eastern boundary

is on the meridian 10 miles east of the most easterly point of Yellowstone Lake. This point is at the upper extremity of the southeast arm, near the mouth of the Upper Yellowstone. Here the shore of the lake is a marsh, extending at the time of high water to the base of the Yellowstone Range, while at seasons of low water it retreats between 1 and 2 miles to the westward. Hence, the eastern boundary, as at present established, is a very uncertain affair. This line, however, cannot, under any construction of the law, be more than a mile from the 110th meridian west of Greenwich, and on my map of the Park I have taken the liberty of placing the eastern boundary on this meridian.

The southern boundary is, for the same reason, equally uncertain. Its position according to the law is 10 miles south of the southern point of the same lake. On the map, I have represented it as dating from the southern extremity (the head of the southern arm) at the time when the survey was made, *i. e.*, September, 1878.

The west boundary is 15 miles west of the western end of Madison (*sic*) Lake. At the time the law was made, the lake now called Shoshone Lake, and known to be one of the sources of Snake River, was supposed to be the source of Madison River, and was accordingly called Madison Lake. This brings the west boundary line but 2 miles west of the western boundary of Wyoming.

Now that the true relations of the Park with reference to the adjacent Territories are known, it would be much better, on many accounts, to subject its boundary lines to slight changes in order to make them conform to Territorial boundaries and to certain parallels and meridians, especially as this can easily be done at present without interference with private claims, and without throwing outside of the Park any of its matchless wonders.

The changes which I would propose are as follows: That the northern boundary be made coincident with the northern boundary of Wyoming. This would be equivalent to moving this line southward 2 miles. The Mammoth Hot Springs are 4 miles south of the Park boundary, and therefore, after this change, will remain 2 miles within the Park. The eastern boundary should be placed on the meridian of 110° west of Greenwich, or it might even be placed on the meridian of 33° west of Washington, 2.5 miles farther west, without injuring the Park as a wonderland, as in either case the line traverses a heavy and rugged mountain range. The southern boundary should be placed upon the parallel of 44° 10′, thus acquiring a definiteness of position. This change would require that the line be moved north for about 2 miles.

The western boundary should be made coincident with the western boundary of Wyoming, thus throwing it 2 miles farther east. Both lines traverse for the most part a high, rugged, heavily-timbered table land, utterly valueless for any purpose except for the timber which it supports.

By these changes the whole area of the Park will be thrown into Wyoming, thus avoiding all questions as to jurisdiction of territorial government. Again, a great saving will be effected in the survey of boundary lines, as the northern and western lines have already been established, while the southern and eastern boundaries, which are very poorly defined by the law, will be definitely established.

The area of the Park, as at present established, is 3,312 square miles. Its length north and south is 61.8 and its mean breadth 53.6 miles. By the proposed change its length will be reduced to 57.5 and its mean breadth to 49.5 miles, while its area will be reduced to 2,846 square miles.

TOPOGRAPHY.

Heading the Southern Fork of the Columbia and the greater part of the drainage of the Missouri, it lies very high compared to the average of the country thereabouts. Its mean height is not far from 8,000 feet above sea-level. The lowest point in the Park—the mouth of Gardiner's River—is 5,360 feet, while the highest mountain peak—Electric—is 11,155 feet above sea.

The surface is largely made up of level or rolling country, plateau-like in character and heavily timbered. In this plateau many of the streams have cut tremendous gorges. Several groups of mountains diversify the surface, as the Red Mountains and the Washburn group. In the northwest corner rises the Gallatin Range, which separates the Yellowstone from the Gallatin River, and which culminates in the magnificent mountain known as Electric Peak. East of the Yellowstone River and Lake rises a very high and rugged range, which stretches from Union Pass north to the bend of the Yellowstone, a range to which Dr. Hayden has given the name of the Yellowstone Range, and which subsequently Capt. W. A. Jones called the Sierra Shoshone. The southern section of the Park is drained by the various affluents of Snake River, Bechler's Fork, Falls River, Lewis Fork, and Barlow's Fork. This drainage area comprises 682 square miles. It is made up mainly of plateaus, and of high rolling country, most of which is densely timbered.

BECHLER'S FORK.

This stream, named from its discoverer, Mr. G. R. Bechler, at that time topographer of one of the parties of this survey, heads opposite the head of the Madison or Firehole River and Shoshone Lake, being separated from them by narrow, abrupt divides of no great height. Its head and most of its course are through a high volcanic plateau, and for most of its course it is sunken far below the general level in a deep, rugged cañon. The plateau is well timbered with the larger coniferæ. Falls River Basin, into which this stream debouches abruptly, the plateau ending suddenly in a line of cliffs facing to the westward, is a large valley, part of which is open, while a part is covered with a dense growth of large coniferæ, and the ground is cumbered with fallen timber to such an extent that, added to the swampy, springy nature of the soil, the Basin is wellnigh impassable. Of the extent of the Basin I cannot speak, as it extends far to the west and north of the limits of my work. Into it flow several large streams. Besides Bechler's Fork, Falls River, Cascade Creek, and a large northern branch of Falls River enter this basin. This valley has but very little slope, and the streams which enter it are immediately split into a number of channels, with many slues and back-waters, which are interlaced with one another in a complex network. It contains also many stagnant pools and ponds, and multitudes of springs break forth from the base of the limiting cliffs. It is one of the few remaining haunts of the moose in the Northwest.

FALLS RIVER.

This stream heads in the southern slopes of the great plateau which Bechler's Fork traverses, rising in four large springs, which give birth immediately to a good-sized river. Its course is nearly due west, skirting the southern base of this plateau. The divide between this stream and the Snake is very gentle, being, indeed, almost imperceptible. Its

course from the divide to the Lakes Beulah and Hering is very quiet, with a gentle current through grassy meadows, but from the point of its emergence from the former of these lakes, it becomes a brawling, turbulent stream, broken by cataracts and falls, from which it has received its name. These falls, which succeed one another at short intervals, have heights respectively of 12, 6, 12, 40, 20, and 30 feet. Finally, at a point but three or four miles above where the stream debouches into Falls River Basin, occur the Great Falls. These, which are close together, consist of two, each having a clear leap of over 20 feet, closely followed by a third of 47 feet, below which are two smaller ones. The total descent is 140 feet, my measurements agreeing very closely with those of Professor Bradley.*

SNAKE RIVER.

At the south boundary of the Park the Snake divides into two branches, the eastern one of which continues to bear the name of the main stream, while the other, which heads in Shoshone Lake, bears the name of Lewis or Lake Fork. The former stream, which is somewhat the larger of the two, heads in several large branches among high hills and mountains to the eastward. The ultimate head of the main branch is southeast of the Forks, among the mountains on the course of Buffalo Fork of the Snake, in a section of country not yet surveyed. Another, known as Barlow's Fork, heads among the high, timbered hills south of Yellowstone Lake, while another, Heart River, heads in Heart Lake at the base of the Red Mountains. The courses of all these streams are in narrow, cañon-like valleys, closely hemmed in by the mountains.

Heart Lake, the head of one of the principal branches of the Snake, is a beautiful little gem, lying amid dense forests at the eastern base of Mount Sheridan, the highest peak of the Red Mountains. It is about 3 miles long by 1½ in width, covers 3 square miles, and is of a very irregular shape, the resemblance in form to a heart being very slight.

The lake has several small tributaries, most of them from the north and west. One of the principal of them, called Witch Creek, heads in Red Mountain and enters the lake near the northwestern corner. On this creek, extending over most of its course, a distance of 3 miles, is a large collection of hot springs, with a few geysers. This group has been named the Heart Lake Basin. They were probably first discovered by Mr. Evarts, while lost from the Washburn party, in which case Heart Lake is his Lake Bessie. But as they were, with the lake and other surroundings, first mapped with an approach to accuracy by Captains Barlow and Heap, in 1871, the names given by them should stand. From the southeast corner of this lake Heart River flows southward, uniting, after a course of five miles, with Barlow's Fork. The combined streams then pursue a devious course to the southward for a few miles, then, joined on the south boundary of the Park by the Snake, they turn northwest, and finally southwest, towards the Forks. South of the Snake and Barlow's Fork the country rises very rapidly to mountains 9,000 feet in height, standing in meridional ridges, across the north ends of which the river has cut a passage. On the north is a high, trachyte-covered plateau, rising gradually towards the Red Mountains.

* Report U. S. Geol. Survey for 1872, p. 258.

LEWIS OR LAKE FORK.

This stream rises in Shoshone Lake, opposite the heads of the Firehole and Bechler's Fork. Leaving Shoshone Lake, it flows into and through Lewis Lake, then, pursuing a straight course a little west of south, it reaches and joins the main river, at the south line of the Park.

Shoshone Lake is purse-shaped, but, unlike most purses, its point of discharge is at the bottom of the larger lobe. Its greatest length is 6½ miles, its greatest width 4½, while the stricture is but ½ mile across, and its area is 12 square miles. It receives three small affluents, Moose Creek near its foot, Shoshone Creek at its head, and an unnamed stream at the northern end of the lower lobe. Besides these there are a number of small branches, but collectively they contribute very little to the lake. At the head of the smaller and upper lobe of the lake, *i. e.*, at its western end, is a collection of hot springs and geysers, discovered by one of the parties of this survey in 1872, and known as the Shoshone Geyser Basin.

The shore of the lake is almost everywhere bold and densely covered with timber. The stream connecting Shoshone and Lewis Lakes is but 3 miles in length, and is broad and sluggish. Lewis Lake is nearly pear-shaped, the outlet being at the stem end. It is 3 miles long by 2 in width, with an area of 4 square miles, with bold, heavily timbered shores. Besides the main stream, the lake receives very little water from the gulches opening into it.

On leaving Lewis Lake, the stream first passes the western end of the Red Mountains, then enters an inclined table-land floored with basalt, in which the stream has cut a narrow, deep rift, scarcely discernible at any distance, which extends nearly or quite down to the Forks. As I did not follow the stream in this portion of its course, I quote the following description of it from Professor Bradley's report:*

In descending from Lake Lewis, the party found the river banks low and rocky for a short distance before the stream enters a cañon with walls 150 to 200 feet high, in which were encountered sharp rapids and a vertical fall of about 30 feet. Then, for a mile or two, the slopes are gradual, with narrow, swampy bottoms along the river. About three miles below the lake, high, rocky banks indicate the approach to a deep cañon, which really commences at about 3¼ miles, with perpendicular walls on both sides, inclosing a narrow channel with a rapidly-sloping rocky floor, in some places partially obstructed by huge tumbling masses of rock, but apparently without any accumulation of gravel. Considerable rapids occur through nearly the whole cañon, and one fall of nearly 50 feet was noticed. The cañon deepens rapidly to from 700 to 800 feet, with widths of less than half the depths at the deepest precipitous portions, though in some places widening above, so as to have sloping banks at an angle of about 59° from the horizon. About 3 miles down it reaches its culmination and is truly grand. It has none of the brilliancy of coloring so characteristic of the Yellowstone cañon, but the somber tints of its gray, brown, and dark red, lichen-covered rocks, variegated with smaller patches of green and yellow, constitute a peculiar style of beauty, and add greatly to the effect of its narrow, dark depths. The only deficiency is in the supply of water, which is small at this season. The rocks are all volcanic, mostly porphyries and trachytes, with some porphyritic obsidian. Some two miles below the end of the main cañon, the cliffs close in again to the river, for a few hundred feet, for a width of about 200 feet, with a height of 400 feet or more, forming a suitable gateway to the cañon from below.

THE RED MOUNTAINS.

This is a small group of mountains, standing between Barlow's and Lewis' Forks, and rising to a height a little exceeding 10,000 feet. The name is derived from the prevailing color of the volcanic rocks which compose them. The slight indication of a trend which they exhibit is

* Report U. S. Geol. Survey. 1872; pp. 256, 257.

nearly east and west. They are by no means rugged, though many of the slopes are extremely steep. There are twelve peaks in the range, separated into three groups by comparatively low saddles. The highest and most eastern peak is Mount Sheridan, 10,385 feet high. From its summit a most varied, extensive, and beautiful landscape rewards one for the hard climb involved in reaching it. On the west the range of vision is limited by a high plateau, in whose southern slopes head Falls River and a small branch of Lewis Fork. To this plateau we have given the name of Pitchstone Plateau. At the eastern base of this the eye can with difficulty discern the narrow cleft in the basalt in which flows Lewis Fork, running transversely to the line of vision. Farther to the right, at the northern base of Pitchstone Plateau, we see the sparkling waters of Shoshone Lake reflecting the afternoon sun. Approaching the foreground, a broad ribbon of water connects this with Lewis Lake, beautifully set in a dark fringe of dense forest. Beyond these lakes, nearly to the horizon, is an almost unbroken, billowy surface of dark, blackish-green forests, while the horizon line is marked by the sharp, snowy peaks of the Madison Mountains. Farther around is the broad, flat, hardly perceptible swell of the continental divide, densely timbered and dotted with little lakelets. Next appears the western edge of the Yellowstone Lake, whose irregular shape, with long arms, reaching far inland, occupies more than a quarter of the circle of the field of view. Beyond it, to the north, rises the plateau of the Elephant's Back, surmounted, apparently, by the peaks of the Washburn group of mountains. On the northeast, far in the distance, and scarcely discernible against the intense blue of the sky, are the rugged, precipitous peaks of the Yellowstone Range, which, as we turn more to the east, approach the lake, which finally laps the very feet of the highest peaks.

In the foreground, between our mountain and Yellowstone Lake, is a great area covered densely with forests, and broken into great bulky hills.

Southward the view is more limited, being cut off by the confused mass of mountains at the head and on the south side of the Snake. Slightly to the west of south, however, the sharp, lofty spires of the Tétons rise high above the mountain ridge which forms the eastern wall of the Snake River Valley. Thence the eye follows the outline of the Téton range as it trends northward. The needle-like spires change to broader and more massive forms, while the range at the same time decreases in altitude. The timber line gradually nears the summits, then the mountains are covered with forests as the range becomes lower, until finally it terminates in a low gap, by which we pass to the head of Falls River, on the north of which rises Pitchstone Plateau. An unusually clear day discloses many more mountains than have been enumerated here. Professor Bradley counted, from this mountain, 471 distinct peaks, at distances ranging from 30 to 200 miles.

This range is timbered almost to the summits, though the trees near the summits, especially if at all exposed to the severe westerly blasts of winter, are stunted and beaten down. Nearly all of the higher summits are entirely bare of timber, owing, probably, to their exposed position, as the limit of timber is, in this neighborhood, slightly higher than these peaks, or, inround numbers, 10,500 feet above sea.

THE CONTINENTAL WATERSHED.

The continental divide crosses the Park in its southwestern part, having a very winding course, but a general direction nearly southeast

and northwest. Throughout, its character is broad, flat, and ill-defined. It enters the Park on the west, on an elevated plateau west of the Lower Geyser Basin, a plateau of volcanic rock, densely covered with timber, and cut by numerous abrupt cañons, but nearly destitute of water. Along this plateau the divide trends very nearly south. Reaching the heads of the Firehole and of Bechler's Fork, it turns to the east and then to the north, to pass around the head of Shoshone Creek. Here it changes its character, and becomes a rather sharp ridge, the sides of which are deeply cut by small gulches, producing an endless amount of small detail in the topography. North of the eastern part of Shoshone Lake the divide again makes a decided change in direction, returning almost upon itself, and thence runs in a general southeast direction across the remainder of the Park, leaving it at a point south of the south arm of Yellowstone Lake. From the turning point down to Flat Mountain, the divide is somewhere on a broad, rolling swell, the highest point of which is but slightly above Yellowstone Lake. Over a breadth of several miles there is scarcely any perceptible slope, and the broad swell is dotted with lakelets and marshes having no outlets. From the north, the elevation of this portion of the divide decreases southward, reaching its lowest point near Lake Riddle, a lakelet without outlet, at an elevation of 8,000 feet above the sea. This name like the "Great American Desert," has been driven from point to point, finding, like the Wandering Jew, no abiding place, until finally Professor Bradley rescued it from its peripatetic career, attaching it to this insignificant lakelet, where it is not likely ever to be disturbed. Among its past glories, it is to be recorded that on many maps what we now know as Yellowstone Lake appears as Lake Riddle. Flat Mountain, which next bears the main watershed, is, as the name implies, flat. Its broad-timbered summit covers several square miles, while its slopes, which on all sides but the north are very gentle, make the mountain cover a large area of country. The northern slopes, at the base of which lies the Flat Mountain arm of Yellowstone Lake, are rugged and precipitous. By some of the earlier expeditions, *e. g.*, Doane's, 1870, and Barlow & Heep's, 1871, this mountain was called Yellow Mountain from the color of the volcanic rocks on the north face. This name, however, seems to have fallen into disuse.

Southeast of Flat Mountain, the divide follows the crest of a range of rounded hills, timbered to the summits, which carry the watershed outside of the Park.

THE YELLOWSTONE DRAINAGE AREA.

The Yellowstone River heads in Bridger Lake, southeast of the Park, and in the mountains in its neighborhood. One of the forks of the well-known "Two Ocean Creek" also contributes to it. This part of the stream, above Yellowstone Lake, is commonly known as the Upper Yellowstone River. Its course is slightly west of north, in a valley averaging about 2 miles in width, sharply defined by mountain walls which rise abruptly on each side to great heights. The eastern wall is the rugged, volcanic Yellowstone Range, whose peaks reach altitudes exceeding 11,000 feet; while on the west there is an abrupt descent to the valley of a high undulating country, approaching a plateau in character, and of a height of 9,000 to 10,000 feet. The stream is sluggish, and much of the valley, especially in the lower part, is very marshy, so as to be practically impassable. Throughout, it is densely timbered.

The drainage area of this system comprises more than half the area of the Park, being 1,900 square miles.

YELLOWSTONE LAKE.

In one essential respect the scenery of the Yellowstone Park differs from that of nearly all other parts of the Cordilleras, in possessing the element of beauty, in presenting to the eye rounded forms, and soft, bright, gay coloring. The type of Cordilleran scenery is grand, awful, dull with even a touch of the repulsive. The prevailing colors, gray and brown, weary the eye by their uniformity. Water, which forms so essential an accessory to a beautiful landscape, is, in the West, usually wanting. Here, however, the country is dotted with lakes, great and small, while the comparatively moist climate has prevented rapid erosion by keeping the land well clothed with forests, and thus preserving rounded forms.

Among these lakes, Yellowstone is the largest and by far the most important. It is the largest lake, at a great elevation, in North America. It has an extremely irregular outline. It has been likened to the human hand, with the fingers outstretched, and, with certain amendments, this simile may serve for purposes of description. The western arm may be represented by the thumb, if we suppose the thumb so telescoped that its thickness greatly exceeds its length. Delusion Lake may represent the forefinger, detached, separated from the hand by one-third of its length, and shriveled to one-tenth its normal size. The Flat Mountain arm corresponds in position, but in no other respect, to the middle finger. It, too, supposes a miraculous degree of shrinkage. The south arm has the position of the third finger, and requires little or no change to make the likeness good; while the southeast arm, into which flows the Upper Yellowstone, must represent the little finger. This, on the supposition that the hand is that of a base-ball player, and has been hardly used, may support the simile. The upper joint has evidently been bent over and the whole upper part of the finger badly swollen; indeed, the whole finger is considerably swollen, as it is evidently the largest of all.

The length of the lake from the head of the southeast arm to the foot of the lake, a direction nearly northwest, is 20 miles, and its breadth, from its eastern shore, in a westerly direction to the head of the west arm, is 15 miles. Its area is 150 square miles. It contains a number of small islands: Stevenson's, near its foot; Dot and Frank's in the middle, if so irregular a lake can be said to have a middle; Mollie Island and a small companion, near the head of the southeast arm; Peale's Island and a companion, in a corresponding position in the south arm; Carrington's in the west arm, and a rock known as Pelican Roost, just off Steamboat Point.

The lake was sounded on a number of lines by Mr. James Stevenson, in 1871, giving a very good idea of its depths. The results of these soundings have been transferred to the accompanying map.

The shores of the lake are nearly everywhere densely wooded with a large, fine growth of coniferæ. In some places the live growth stands above and among a cobwork of fallen timber, placed like an abattis of Dame Nature to prevent man's trespassing. The slopes to the lake are for the most part gentle, easy descents, with a mud or pebble beach. Such they are from the outlet to the head of the south arm, broken only in two or three places by bluff or rocky points. The broad projection between the west and Flat Mountain arms is very low, but little above the level of the lake, and very marshy, being dotted, especially at times of high water, with many ponds. Of these, the largest, and, indeed, almost the only permanent one, is Delusion Lake, so long supposed to be an arm of Yellowstone Lake. Indeed, there is no certainty

that in the spring time, when the Yellowstone range and all the high country thereabouts is disgorging its winter accumulations of snow, this lake does not have a broad water connection with the larger lake; in other words, it may for a short time be the fore finger.

Flat Mountain makes a most decided break in the uniformity of the slope of the shore-line. The mountain rises 500 feet above the lake, and all this height is represented by a precipitous, rocky slope from the summit to the margin of the water. On the east, however, Flat Mountain slopes uniformly and gently down to the shore of the south arm. Flat Mountain arm has a length of 3 miles, with a mean width of less than half a mile. The corresponding dimensions of the south arm are 8 miles and 2½. Between the south and southeast arms is a long, narrow projection known as the Promontory. From a low isthmus, but little above the lake near the head of these deep bays, it rises to a height of 1,000 feet above the lake, at the same time broadening from 1 mile to 2. It ends abruptly in a rocky precipice facing to the north.

The head of the southeast arm is in part limited by a steep wall, the same which borders the valley of the Upper Yellowstone on the west, and in part by this marshy valley. The border of the lake is here very ill defined, the marsh extending inland for at least 2 miles to the eastward from the clear water of the lake.

Proceeding down the eastern shore of the lake we find a succession of valleys, opening out on the shore and mountain spurs, terminating abruptly at the water's edge.

Beaverdam Creek is a large mountain stream, occupying the first of these valleys, and entering the lake very near the head of the southeast arm. Three miles above its mouth, just within the mountains, it receives a large branch from the right, known as Rocky Creek.

North of this stream, a heavy mountain spur, headed by the fine peaks Langford, Doane, and Stevenson, and bearing many minor summits, reaches from the crest of the Yellowstone range to the shore of the lake. Then follows a broad valley, drained mainly by Milky Creek, north of which is the spur known as the Signal Hills. Then succeeds a third valley, in which are three creeks of considerable size, all heading in the mountains, besides several smaller ones heading in springs and swamps in the dense forest. There follows then a third spur from the mountains, terminating on the border of the lake with a round-topped hill, which I have named Lake Butte.

Next we come to the valley of Turbid Creek, on whose lower course, near the lake-shore, is quite a large collection of hot springs. This stream heads in the mountains about Mount Chittenden, and flows through Turbid Lake, a small body of water which is rendered milky from the numerous sulphur springs which dot its shore.

Beyond the mouth of Turbid Creek the lake shore runs out in a bluff point, named from a spring on the extreme point, Steamboat Point. Passing this point we see the shore retreating in smooth, graceful curves, making Mary's Bay. A mile east of this the lake receives its largest affluent, next to the Upper Yellowstone, in the form of Pelican Creek. This stream heads among high timbered hills to the northeast, against the East Fork of the Yellowstone. Comparatively little of its water comes from the high mountains of the Yellowstone range, its drainage area comprising little more than the foot-hills. It heads in three large branches, two coming from the north and the third from the east, the three uniting within a hundred yards of one another. A fourth large branch, Lake Fork, coming from the north, joins the stream about a mile below the forks. The lower course of the stream is very sluggish

and marshy; the forests which are almost omnipresent in the Park are here wanting, the broad valley being open and almost entirely devoid of timber. At its mouth the swamps develop at times of high water into a small lake or lagoon. Between the lower course of this stream and the head of the Yellowstone proper, a low ridge runs out from the high hills to the northward to the lake.

Besides the streams above mentioned, the lake receives no large affluents, though a number of small streams empty into it on the west and south. Bridge Creek, so named from a natural bridge which spans it, is a small stream which comes in from the west, some four miles south of the outlet. Besides this a stream about the same size comes in about a mile farther north. On the northern shore of the west arm a good-sized creek comes in, and on the western shore the lake receives four or five small streams. A small creek comes into the head of Flat Mountain arm, and the south arm also receives several small streams. The southeast arm receives, besides the Upper Yellowstone and Elk Trail Creek, a small stream which flows along the west edge of the valley of the Upper Yellowstone, draining the hills on the western side for a distance of 6 or 7 miles from the lake; also a second stream from these hills, which has its course west of the latter.

THE YELLOWSTONE RIVER.

This river, the largest and most important branch of the Missouri, issues from the lake at its northern end, and for 105 miles holds a generally northern course. At the mouth of Shields' River, near the site of the old Crow Agency, it turns east, and after holding this course for several hundred miles, it again turns to the northeast and continues in this direction to its junction with the Missouri at Fort Union.

From its point of exit from the lake nearly down to the Upper Falls, the river is broad and sluggish, full of aquatic plants, and frequented by large flocks of ducks, geese, and other aquatic birds. The gentle, easy current is broken only in a few places by slight rapids which afford easy and safe fords. The immediate valley varies much in width, but is for the most part narrow. On the right (east) the country rises quite rapidly at first, to a mass of flat-topped hills, in which head Sour Creek, a branch of the Yellowstone, and several branches of Pelican Creek. On the left the topography is more decided. A heavy, broad, plateau-like ridge, known as Elephant's Back, abuts against the river just below its exit from the lake. This ridge at first trends westward for 6 or 7 miles, with an elevation of 8,800 feet, separating the drainage of the lake from that of the river. Then it gradually sweeps around to the north, and becomes the watershed between the East Fork of the Fire-hole and Alum Creek, an important branch of the Yellowstone. This ridge finally fades out in the high plateau region about the heads of the latter stream and Gibbon River, after sending a long spur down to the Yellowstone River, forming the northern watershed of Alum Creek. The space inclosed by the semicircular ridge just described and the river, drained by Alum Creek and other smaller branches of the Yellowstone, is elevated but little above the level of the lake, and was formerly occupied by it. It is an oasis of open country, covered with grasses and artemesia, amid a wilderness of forest.

At the head of Alum Creek, on the summit of the divide, is a large collection of hot sulphur springs, the waters of which have collected at the foot of the springs into a pond, which feeds the creek. Another extensive group of springs occurs on a small branch of this creek, at

the base of the ridge. These springs are, from the color of their deposits, known as the Violet Springs, and the branch which they supply with water is known as Violet Creek.

A short distance above the mouth of Alum and Sour Creeks, which join the Yellowstone very close together, are the Crater Hills, on and about which are very fine hot sulphur springs, while all about, covering several square miles, the country is encrusted with their deposits.

About a mile above the Upper Fall the river breaks into rapids, then into a succession of lively cascades before rushing over the cliff at the Upper Fall. At the crest of the fall the river is contracted to a width of about 80 feet, and is shot out to a considerable distance, so that in all probability there is an abundance of room to pass under the fall.

The Lower Fall is about half a mile below the Upper, the current of the river between them being quite rapid. At the brink the river is 100 feet wide, with an unknown depth. I shall not burden the reader with an extended description of these falls, which have been amply illustrated by the reports of others.

This year I was enabled to make careful, direct measurements of them by means of cords, and have obtained results which may be depended upon. The Upper Fall was measured by dropping a weighted line from the top of the overhanging cliff immediately adjoining the fall, to the level of the water at its base, thus obtaining as correct a measurement as could be desired. This measurement gave 112 feet as the clear height of the fall.* This result, as compared with the height (140 feet) which I obtained in 1872 from barometric measurement, simply gives another illustration of the uncertainty attending such work, even when made under the most favorable circumstances. In this and in other similar cases, the fact that the height as measured by barometer is greater than the true height, it seems to me, may be explained by the downward rush of air at the lower station, which, of course, would produce an abnormal pressure at that point.

My measurement of the Lower Fall was not as simple in method, and allows more room for error than in the case of the Upper Fall. I found a point, by means of the clinometer, on the eastern wall of the cañon and very near the fall, at the same level as its top. Thence I stretched the line down the cañon wall to the level of the foot of the fall, reaching it at a point so close that we received a thorough drenching from the spray. Then, with a clinometer, I measured as accurately as possible the angle of inclination of the line. This gave as the height 297 feet. Though this result cannot be regarded as strictly accurate, still its error must be small; and in round numbers, 300 feet may be regarded as a close approximation to the true height. Ludlow measured this fall directly by means of a sounding line, obtaining 310 feet as the height, a result agreeing quite closely with mine, especially when one reflects on the difficulty of determining when the weight was at the base of the fall, in the cloud of mist and the rushing river. Most of the other measurements are barometric. Such was that of Captain Jones, who gave a height of 328.7 feet.

The measurement made by Mr. N. P. Langford in 1870, and first published in the report of Lieutenant Doane, gave a height of 350 feet to this fall. It was made with a line stretched on an incline, but there was no way of measuring with any approach to accuracy the angle of the

* Captain Jones, in 1873, by barometric measurement, found this fall 150.2 feet high; while Lieutenant Doane, in 1870, by a line, found a height of 115 feet; and Ludlow, by the same method, 110 feet; the last two of which agree very closely with my own.

Divide Lake, between East Fork and Pelican Creek.

slope. The measurement which I published in 1872, which was so wide of the mark, was made by a comparison of the vertical angles subtended by a tree at the head of the fall, whose height had been measured, and by the fall. Probably here the source of error was in sighting at the base of the fall, which was very ill-defined, owing to the immense amount of spray and vapor.

I measured the volume of water in the river just at the head of the rapids above the Upper Fall, at the end of August. The amount of water carried by the stream was found to be 1,200 cubic feet per second. This result is little, if any, below the average of the year.

A marked feature of this stream is certain to strike the observer; that is, that it shows no signs of floods. The river flows very nearly bank-full all the year and this although most of its water comes from high mountains. There is no broad flood-plain of bare gravel and bowlders strewn with wrecks of forests. The explanation is as simple and apparent as the phenomenon. The river has a balance-wheel in the form of the lake, by which inequalities of supply are leveled down. It is probable that the river, from the foot of the lake to the mouth of its East Fork, does not vary in level a foot between its highest and lowest stages. The case of Lewis Fork of the Snake is similar, and there we find a similar absence of evidences of floods. Were this idea, thus given to us by nature, carried out on all these mountain streams, the sources of the Missouri, Platte, and Arkansas, the question of controlling the Mississippi in its lower course would be vastly simplified, while the water would be stored for use in reclaiming great areas of land, otherwise arid and desert.

About half way between the two falls, Cascade Creek, a small stream which heads in the southern slopes of the Washburn Range, falls into the river. A few hundreds of yards above its mouth this little stream makes a succession of beautiful cascades, to which the name Crystal Falls has been given. They are three in number, and placed so closely together that they almost form a continuous fall. The total height is 129. Though the amount of water in the stream is small, still from its graceful form this little fall is well worthy a visit.

THE GRAND CAÑON.

This feature, too, has been so frequently described that anything further concerning it is almost superfluous. Commencing at the Falls it extends down nearly to the mouth of the East Fork, a distance, as the river flows, of 24 miles. Indeed, from the falls to the mouth of Gardiner's River the Yellowstone is in a continuous cañon, but the partial break at the mouth of the East Fork separates it into two parts, known as the Grand and the Third Cañons. The former occupies the line of greatest depression in a volcanic plateau, which slopes to the northward and southward from the Washburn group of mountains, and to the westward from the Amethyst Ridge of the Yellowstone Range. Its course is northeast as far as the extremity of the Washburn group, and, after passing that, it turns north with a very slight inclination west. The height of the plateau at the falls is about 7,800 feet. It increases slightly northeastward, until, in passing the mountains, it has an elevation of about 8,000 feet. Thence northward it decreases in height rapidly, and at the mouth of Tower Creek it reaches but 7,200 feet. At the head of the Upper Fall the river level is but a few feet below the top of the plateau. This fall adds 112 and the Lower Fall 300 feet to the depth of the chasm. From the foot of this fall to the mouth of East Fork

the total fall is 1,304 feet in a distance of 24 miles, being an average of 54.3 feet per mile. As far as the extremity of the Washburn Mountains, a distance of 12 miles, the cañon continues to increase in depth, both by the fall of the stream and the rise of the plateau, and the extreme depth, 1,200 feet, is attained at this point. Thence the depth decreases rapidly, and at the mouth of Tower Creek it is but five or six hundred feet deep on the west side, and about 1,000 feet on the east side. The width of the cañon at the top ranges from one-fourth of a mile to one mile, and the angle of slope of the walls from the top to the water's edge ranges from 45° to 75°, with a horizontal line.

The Yellowstone receives several tributaries from each side in its progress down the cañon. From the east, Jasper, Agate, Broad, and Orange Creeks come in, and from the west a number of small streams, heading in the Washburn Mountains. As is usually the case in a land of cañons, these branches have much less erosive power than the main stream, and consequently reach it at a much higher level, necessitating a very rapid slope at the end or an abrupt fall. Many of these streams make very fine falls in reaching the cañon walls. This is particularly the case with the little streams on the west. They flow on the surface of the plateau, with a very gentle current, and have to make the whole descent to the bed of the cañon in a small fraction of a mile. The streams from the east, which head high up in the Amethyst Ridge, have long courses and drain considerable areas. These streams cut cañons of considerable depth before they reach the main stream.

THE WASHBURN MOUNTAINS.

This group stands near the middle of the Park in longitude, and in latitude about one-quarter the length of the Park from its northern boundary. It is in the form of a semicircle, the middle of the convexity being towards the southwest and opening towards the Yellowstone. Its diameter is about 8 miles. The whole of this great amphitheater is drained by Tower Creek and its branches. The group contains altogether about twenty-five summits, ranging in height from 9,000 to 10,400 feet. The highest peak of the group is Mount Washburn, 10,346 feet above sea-level. This peak is very easy of access, and as the trail up the river passes very near the summit it is a very much-visited mountain. Card-receivers, consisting of old peach and sardine cans, are crammed with the names of visitors, from Cabinet officers down to the Toms, Dicks, and Harrys of the great unwashed. The earliest date is that of Lieutenant Doane's (the Washburn) party, 1870.

Southwest of Mount Washburn, and distant from it but 2 miles, is a sharp cone rising to a height of 9,988 feet. This I have named Dunraven Peak, in honor of the Earl of Dunraven, whose travels and writings have done so much towards making this region known to our cousins across the water. This is the peak which rises directly up from the west side of the pass in the Washburn Mountains, on the trail to the Falls.

The southern slopes of the convexity of the Washburn Mountains are drained by small streams flowing into the Yellowstone, the largest of which is Cascade Creek. This stream collects its waters during a very leisurely course through a series of marshy meadows, and enters a cañon only a mile above its mouth. The western slopes of these mountains are tributary to the East Fork of Gardiner's River, while most of the northern slopes drain into the Yellowstone through Blacktail, Geode,

Upper Falls of the Yellowstone.

and Elk Creeks. While the former are quite abrupt, the latter are very gentle and gradual.

The timber-line in this group is at about 10,000 feet above sea, some of the highest peaks reaching above it.

TOWER CREEK.

This stream drains the great amphitheater inclosed by the Washburn Mountains. The stream has three main branches, the uppermost, which continues the name of Tower Creek, Carnelian Creek, which heads in the pass crossed by the trail, and Antelope Creek, which heads in Mount Washburn and flows into the main stream only a hundred yards above its junction with the Yellowstone. The latter is the only branch which has a valley, as the others flow in mountain gorges in their upper courses, changing to plateau cañons farther down. This, although a good-sized stream, has not cut its bed down to the level of the Yellowstone, but at a point about one-quarter of a mile above its mouth it leaps over a cliff 132 feet high* into a deep, dark, gloomy gorge, down which it hurries to join the river. The scenery of this fall is very fine. Above, the stream is a rapid torrent, rushing down a steeply inclined bed, paved with great bowlders, and inclosed between precipitous walls 300 to 400 feet high. At the brink of the falls erosion has left standing many tall, acicular spires of volcanic conglomerate, which give the name to the Fall. From below, we see these spires continued downwards to the lower level, in bas-relief, on the faces of the cliffs. The fall is a clear leap, unbroken by any projection, and the gorge below is so deep and narrow that the sun's rays seldom penetrate it and dispel its gloom.

Descending gradually from the plateau, we enter a small valley on the west side, at the base of the eastern cusp of the Washburn Mountains. The floor of this valley is elevated 200 to 300 feet above the level of the river, whence it descends by steep bluffs.

THIRD CAÑON OF THE YELLOWSTONE.

The cañons on the river are numbered from below. The first or Lower Cañon is a short distance above the great eastern bend of the river, the second extends from a point about 10 miles above the well-known ranch of the Bottler Brothers to Cinnabar Mountain and the Devil's Slide, while the third, commencing at the mouth of Gardiner's River, extends up to the mouth of the East Fork. This differs in many important respects from the Grand Cañon. Though largely carved from volcanic rocks, it is by no means as precipitous. In some places it is cut in granite. The walls are much less even, being broken down in many places. On the south, the country bordering it is a rolling, uneven plateau, covered with grass and sage, with timber only in groves. On the north side the walls are formed by the foot-hills of the Yellowstone Range, which gives a very different character to the orographic forms. Indeed, the walls are so irregular that it is very difficult to speak at all concerning the depth of the cañon. It may be said, however, that the plateau ranges from 7,000 to 8,000 feet, while the river, which, at the mouth of East Fork, is 5,978 feet above the sea, has an elevation at the mouth of Gardiner's River of 5,360 feet. There is no point in this cañon where either wall exceeds 2,500 feet in height.

*Barometric measurement, 1872. Doane makes it 115 feet, Barlow and Heap, 156 feet. Their methods of measurement are not given.

The plateau on the south side of this cañon consists of a long, gentle slope to the northwest from the Washburn Mountains, terminating in a shallow trough extending across the plateau, then a gradual rise towards the north to a summit, followed by an abrupt slope northward down to the river. Most of this plateau is drained by Blacktail and Geode Creeks, which head in the Washburn Mountains. The long branches of the former stream come down the slope of the plateau, collect in the trough above mentioned, and, re-enforced by small streams from the northern slope, break through to the Yellowstone. On the west and north of the depression or trough the plateau breaks down abruptly to the valley of Gardiner's River in a sheer cliff 2,000 feet in maximum height. The summit of the plateau above this cliff is known as Mount Evarts, in honor of a member of the Washburn party, who succeeded in immortalizing himself by getting lost near the south shore of Yellowstone Lake.

GARDINER'S RIVER.

The stream, one of the principal branches of the Yellowstone in its upper course, heads in three large branches, known, in the limited vocabulary of the mountains, as the East, Middle, and West Forks. Of the three the West Fork is by far the smallest. It heads in Sepulchre Mountain, an outlying peak of the Gallatin Range, flows at first south down an open valley, then turning east it cuts through a mountain ridge, which limits the valley of the main Gardiner's River on the west, making a fine fall in the cañon.

The Middle Fork, much the largest of the three, receives most of its water from the Gallatin Range, while some good-sized branches come from the timbered plateaus to the southwest and south. Its longest branch heads in Electric Peak, the highest and finest mountain within the limits of the Park. The stream flows thence south in the same broad, open valley with the West Fork, collecting stream after stream as it issues from among the mountains. Finally, turning eastward, it receives the waters collected from the many springs on the plateaus, cuts its way through the ridge encountered by the West Fork, and is joined by it in the valley below. In the cañon this stream, like the West Fork, makes a very fine fall.

The East Fork joins the main stream about half a mile below the junction of the other two branches. It continues up at first in a southeast course, then turns to the west, and heads in the western and northern slopes of the Washburn Mountains and in the timbered plateaus lying west of them. This stream also makes a fine fall at a point 2 or 3 miles above its junction with the main stream.

Below the junction of these branches, Gardiner's River flows north, making a very straight course to the Yellowstone, bordered on the right by the cliff of Mount Evarts, on the left by a steeply-sloping valley, which terminates in a low cañon wall on the margin of the river.

The celebrated Mammoth Springs are situated about 4 miles above the mouth of the river and 1½ miles back from it, and are elevated above it nearly 1,000 feet.

THE EAST FORK OF THE YELLOWSTONE.

This, the largest branch of the river, in its upper section, heads entirely in the Yellowstone Range, and enters the main stream between the Grand and Third Cañons. Its extreme southern branches drain the mountains as far to the south as the northern shore of Yellowstone Lake, while its

Yellowstone Cañon and Falls.

extreme northern branches head opposite those of Clark's Fork of the Yellowstone. It is, in the main, a rapid stream, and is subject to extreme freshets, as is shown by the ragged condition of its bed, by its rapid erosion, and by the enormous deposits of gravel, bowlders, and dead timber wherever its current is checked. Its course, after the first gathering together of waters, is nearly northward for 25 miles along the base of the Yellowstone Range. It is separated from the Yellowstone by a high, broad ridge, the northern part of which is known as Amethyst Ridge. In this part of its course it is joined by several large streams from the east, which head far in the recesses of the mountains. Of these the largest is Soda Butte Creek, a stream nearly equal in size to the main stream above their junction.

Finally, having reached the end of the Amethyst Ridge, the stream turns west, flows in this course for about 7 miles, and falls into the Yellowstone.

Above Soda Butte Creek the stream is in a cañon, bounded on either side by very high but not precipitous walls. On the right rise the mountain slopes; on the left is a high, rolling country, intersected by shallow valleys, running east and west, *i. e.*, nearly transverse to the courses of the main streams. In each of these valleys are two streams, one flowing east to the East Fork, the other west to the Yellowstone, with a very slightly-marked divide between them. These valleys are bare of timber, forming beautiful little parks, while the ridges between them are densely timbered.

Traveling northward on this divide, between the Yellowstone and its East Fork, we soon leave most of the timber, and, rising a few hundreds of feet, find that the divide has changed its character. It has become a sharp ridge, broken into summits, sloping to the Grand Cañon, and pitching off abruptly to the East Fork, which here, below the mouth of Soda Butte Creek, is meandering lazily down a broad valley, with many crooks and windings. The valley here, for 6 miles, has an average width of about 2 miles. The divide here is known as Specimen Ridge, and one of its summits, on which many fine amethysts have been found, as Amethyst Mountain.

THE YELLOWSTONE RANGE.

This name has been given by Dr. Hayden to the great range which extends from the Yellowstone River southward to Union Pass, and separates the drainage of the Big Horn from that of the upper course of the Yellowstone. It is the range to which Captain Jones, in 1873, gave the name of Sierra Shoshone, under the mistaken idea that it had not yet been christened. His claim to the privilege of naming it is thus stated:*

> As I have been the first to cross them and mark out their geographical position and extent. Professor Hayden has called what he has seen of them and their western border sometimes the "Snowy Mountains" and sometimes the "Yellowstone Mountains," but he has also applied the latter name to a range lying south of Yellowstone Lake that has no existence.

As to the first statement: Captain Jones has crossed this range at two points—at Stinking Water and Togwotee Passes—both near the southern end. He has mapped from his own work, in a rough way, the portion of the eastern slope between these passes, and the range in the neighborhood of these passes. At least three-fourths of the range he never saw. All this was in 1873.

* Report on Reconnaissance of Northwestern Wyoming, p. 21.

In 1871 and 1872, Dr. Hayden's survey mapped, also in a rough way, it must be confessed, the whole western slope of the range, from the south line of the Park to the north end of the range, ascending no less than six of the dominant peaks, and crossing the range in two places, at the heads of Soda Butte and Slough Creeks. Again, I have been unable to find a reference to this range wherein Dr. Hayden speaks of it as anything else than the "Yellowstone Range," and this name recurs in his reports repeatedly. In one place he speaks of it as being represented *on old maps* as the Snowy or Heart Mountains. The fact that on a map of Yellowstone Lake the name Yellowstone is applied to a range south of the lake is due to an error of the draughtsman solely. And, in passing, I may remark that the range in question *has* an existence, Captain Jones to the contrary notwithstanding, if a mass of country 2,300 feet above the lake and 10,000 feet above the sea has any claims to the name of mountains.

Throughout its whole extent this range is extremely rugged. That portion of it lying within the Park is almost entirely volcanic, only a small portion of it near the north line being of granite. It occupies a great breadth, and its peaks range nearly up to 12,000 feet in height. The highest peak yet measured is Index Peak, which stands 4 or 5 miles east of the Park, and has an elevation of 11,702 feet. There are probably many higher peaks, as the great bulk of the range has not yet been explored.

The first large stream entering the Park from these mountains is Hell-Roaring River, which flows into the Yellowstone in the third cañon. It comes from the granite portion of the range north of the Park, cutting a tremendous gorge through it. Reaching a low plateau at the base of the mountains, it changes its course from south to nearly northwest, flowing nearly parallel to the Yellowstone for several miles before falling into it. In the bend of the stream stands a high, sharp, conical peak of granite, a well-known landmark in this region, known as Hell-Roaring Mountain.

The next stream draining Yellowstonewards is Slough Creek, a large branch of the East Fork. At its head a low divide leads over to the head of the Rosebud. Next in order is Soda Butte Creek, a second very large branch of the East Fork. At its head easy passes lead over to the heads of the Rosebud and Clark's Fork of the Yellowstone. About the heads of this stream the mountains become extremely rugged. They are made up of volcanic conglomerate disposed in beds or strata, which have been eroded in such a way as to leave cliffs of various heights, from a few feet only, to thousands of feet. The profiles of the peaks show a succession of steps, of varying magnitudes and relations between the rise and the tread. In this group, and just without the boundary of the Park, are Index and Pilot Peaks, two of the best known landmarks in the region. At their base is the Clark's Fork mining district, at the head of the stream of that name.

South of Soda Butte Creek for a few miles the mountain-forms are less pronounced. Two large eastern branches of the East Fork flow in from a region of smooth, easy, timbered slopes; but at the extreme head of the East Fork the mountains again show themselves in all their original ruggedness. A near view of this portion of the range is surpassingly grand. The material upon which nature has here worked, volcanic conglomerate, is not such as produces spires and pinnacles of the Gothic order, but mainly great, broad masses with precipitous sides and flat summits.

The extremest southern branches of the East Fork head as far to the

Crystal Falls.

south as latitude 44° 35′, opposite branches of the Stinking Water, a large tributary to the Big Horn River.

South of the head of the East Fork the tributaries to the Yellowstone, whether they flow into the lake or into the Upper Yellowstone, are comparatively short, the divide between the Yellowstone and the Big Horn swinging to the eastern part of the range. The mountains also rise more abruptly, with a smaller breadth of foot-hills. Of the prominent peaks in this portion of the range may be mentioned Mount Chittenden, named for Mr. George B. Chittenden, whose name has long been identified with this survey. This fine, prominent peak stands at the head of Turbid Creek, and of a branch of Pelican Creek, while from its eastern base flow the headwaters of the Stinking Water. From its neighborhood a heavy spur runs down to the lake, terminating in Lake Butte. South of this is a deep bay of low country, partially swampy, at the head of which is a very low pass to a branch of the Stinking Water; and, judging from the number of old trails setting in that direction, it is probable that the pass in question is much used by game and Indians. Though it was not practicable to measure its height, it can be but little above the lake, as the slope upwards to it is scarcely perceptible, and the summit is very ill-defined. The stream from it to the eastward has a rapid descent, in a close cañon between high mountains. This bay is limited on the south by the spur known as the Signal Hills, which consist of a series of half a dozen hills running down to the lake shore, each lower than the one west of it, and connected with it by a low saddle.

Next follows a broad valley, drained by Milky Creek, then a high spur, at the head of which stands Mount Langford, named, in 1871, for ex-Gov. N. P. Langford, formerly of Montana. On the spur are two very fine conical peaks, the higher bearing the name of Mount Doane, from Lieutenant Doane, U. S. A., who was in charge of the escort of the first party that explored the Park (General Washburn's); the other, Mount Stevenson, from Mr. James Stevenson, who for many years was the executive officer of this survey.

This spur reaches the lake at its head. South of it the cañons become closer, while the belt of foot-hills and secondary peaks becomes much narrower, and in a few miles entirely disappears, and the highest peaks look directly down upon the valley of the Upper Yellowstone. Farther yet, and the range assumes more the appearance of a high plateau, erosion having acted but little upon the original mountain mass. Some of the earlier maps represent a peak in this neighborhood marked as Mount Humphreys, but I have been unable to identify it.

THE GALLATIN RANGE.

This range separates the Yellowstone from the Gallatin River. But a small portion of it, in length only 15 miles, is within the Park, while it extends northward for a long distance, finally disappearing only against the Missouri River, below its great bend. It is not, however, known as the Gallatin Range throughout. West of Bozeman and Fort Ellis it is very much depressed, falling to an elevation of only about 8,000 feet, and north of this depression it is known as the Bridger Range.

Within the Park the first peak is Electric, the highest and finest peak in that reservation. It has a height of 11,155 feet above sea, and of 6,000 feet above the valley of the Yellowstone at its base. Its summit is double, the eastern peak being the higher. The summit of the latter is very small, not covering a space greater than 10 square feet,

while on all sides but the west, where a knife-like ridge connects with the west peak, sheer precipices extend downward for thousands of feet. The view from this summit is very impressive. North of us, and almost at our feet, the Yellowstone winds its sinuous course down a beautiful valley. In a few miles it flows in among densely-wooded mountains, where it is lost to sight for several miles; then it reappears, more distant, in a second valley, down which it flows until lost in the haze of the distance. East of this stream rises the Yellowstone Range, whose snowy peaks limit nearly half the horizon. East of us Sepulchre Mountain seems but a stone's throw away, and below it is the lower valley of the Gardiner, with the white hill of the Mammoth Springs and the long, straight cliff line of Mount Evarts. From the crest of this extends eastward the plateau of the Third Cañon, while the line of the cañon is scarcely discernible. Farther to the right are the flat summits of the Washburn Mountains. Turning to the south we look down the broad, open valley of the upper waters of Gardiner's River gradually rising and changing into the densely-wooded plateaus about the heads of the southern branches of this stream and Gibbon Fork, and far above it all rises the needle-like peak of the Grand Teton. A few degrees farther to the right include the peaks of the Gallatin Range, over which we see the timbered valley of the Madison, Tyghee Pass, and the mountains about Henry's Lake. To the west and northwest the view is one of peaks, mountain rising above mountain, seemingly in endless confusion, a sea of mountains whose white-tipped waves are sorely vexed by contrary winds.

The mountain is not difficult of access. It can be approached from the north by following up the valley of Trail Creek and riding up the spur next to the peak. By taking this route one can ride nearly to the summit. A shorter route is from the valley of the Middle Gardiner, south of the peak; but here the climb would necessarily be much more concentrated, though shorter, and a much greater distance would require to be made on foot.

Electric Peak is not on the divide between the Yellowstone and Gallatin, but, as is so often the case, the watershed follows a lower and far less prominent ridge, the peak being on a spur separating Gardiner's River from several small streams draining directly into the Yellowstone. This watershed passes three or four miles west of Electric, with a general southward course, but with many windings. It keeps on the west side of the body of the range, presenting an abrupt wall to the westward, with long, heavy spurs, in most cases exceeding in height the watershed itself, trending off to the eastward, and breaking off abruptly in precipices to the valley of the Middle Gardiner. The streams on the east side of the watershed all drain into the latter river, and all flow, while in the mountains, in U-shaped cañons. Altogether the range sends down to the eastward five large streams—Electric, Fawn, Panther, Indian, and an unnamed stream from the south of Mount Holmes.

The structure of this range is very peculiar. It is made up of stratified rocks, dipping northward, *i. e.*, nearly in the trend of the range. Its eastern portion appears to have been eroded away, leaving a line of cliffs at the ends of the spurs. Some of the creeks coming from the mountains have cut cañons, with precipitous walls on both sides, while others have a precipice on the north, while on the south the slope is gentle, following the dip. Electric and Fawn Creeks are of the latter class, while Panther and Indian Creeks are of the former. Quadrant Mountain, between Fawn and Panther Creeks, has a very peculiar shape. The summit, with the northern and western slopes, form a

Grand Cañon of the Yellowstone.

curved surface, roughly resembling a segment of a sphere. On the east and south are almost sheer cliffs from base to summit. On the summit is a little nipple, rising a couple of hundreds of feet above the main mountain, the last remains of higher beds.

The range ends abruptly in Mount Holmes, one of the finest and most prominent mountains in the Park. I have named it after Mr. W. H. Holmes, who has been connected with the survey as geologist and artist since 1872. Farther to the south the divide between the heads of Gardiner's and Gibbon Rivers on the east and the Madison on the west (for in this latitude we are beyond the head of the Gallatin) is borne on a mere swell in the plateau.

THE MADISON DRAINAGE AREA.

Area within the Park, 730 square miles. The Madison is the middle one of the three forks of the Missouri which join at Gallatin City. The portion of the river within the limits of the Park is known more commonly as the Firehole. The stream heads just west of Shoshone Lake, separated from it and the head of Bechler's Fork by relatively low divides. At high water the stream has its source in a small pond, a hundred yards or more across, known as Madison Lake. In the dry season this pond ceases to exist, although a bit of marshy ground indicates its site. The stream at first pursues a northeast course in a narrow valley, then comes a bit of cañon, followed by a like succession of open valley and cañon. The valleys are narrow and marshy, and traveling is not easy. In the second bit of cañon, about 8 miles from its head, the stream turns to the northwest, and in 3 or 4 miles flows out into the Upper Geyser Basin. So far the stream has received no large branches. The principal branch in this portion of its course comes down a deep cañon from the east and enters it at the head of its bend. The stream, however, has grown very rapidly, but it is mainly from springs along the edges of the valley

The Upper Geyser Basin is a valley of about a dozen square miles, nearly flat as to surface, and surrounded by bluff, rocky walls on all sides, except where the Madison (Firehole) and its branches enter and find exit. A full description of this basin, with the others, will be found in Dr. A. C. Peale's report, so that it is unnecessary to enter into further description. At the foot of this Basin the river receives two large branches from the west, Little Firehole River and Iron Spring Creek, which join one another just before entering the main stream.

A few miles of a northerly course, in a narrow valley, between high timbered hills, and the Firehole flows out into the Lower Geyser Basin, a somewhat larger valley, containing about 20 square miles, and limited, but not as closely or abruptly as the Upper Basin, by high hills. At its head a small stream comes in from the east, while at its foot two large streams join it from the west—Sentinel and Fairy Fall Creeks, and a second stream from the east, known as the East Fork of the Firehole. This is a large stream, heading in the Yellowstone divide, opposite Alum Creek and other smaller streams. It has many branches, with short, steep courses, which collect in a basin at the base of the divide, whence the stream pursues a course nearly west, down a narrow valley between high, steep walls. The country south of it and east of the Firehole is high and undulating, with little drainage, and covered with a dense growth of timber.

The Firehole continues in a northwesterly course for 5 miles below the mouth of East Fork, when it is joined by Gibbon River, a large branch nearly equal in size, heading off to the northeast among the densely timbered plateaus opposite the head of Gardiner's River. In

its course between the mouths of these two streams the Firehole has a very rapid current over a bottom broken by immense bowlders, and in one place makes a very fine fall of 60 feet in height.

As was said above, Gibbon River heads in the heavily-timbered, marshy plateaus opposite the heads of the southern branches of the Middle and East Forks of Gardiner's River. The region in which these streams head seems to consist of a succession of broad ridges, trending north and south, and of narrow valleys, in which there are in many cases, low divides, from either side of which a stream flows, one to Gardiner's, the other to Gibbon River. In this way nearly all the larger branches of these streams are connected.

The valleys of these branches are mainly open and very marshy. The streams have but little fall. The two upper branches flow at first toward one another, the one northward, the other southward, in the same valley, meeting near its middle. Then the stream turns to the west and flows in that direction for 2 or 3 miles, receiving a branch from the north, then turns nearly south on entering a large, open meadow, and there receives a second large branch from the north. Crossing the meadow it enters a close cañon, by which it cuts through a high ridge which has limited its drainage basin on the south. In this cañon it has a very rapid current, and at its end it leaps over a fall of about 80 feet. Near this point it turns to a western course and flows thence to its mouth in a narrow valley, with the high ridge above mentioned, rising to a height of 1,500 feet on the right, and the hills separating it from East Fork on the left. The point of junction of the streams has an elevation of 6,872 feet. Below this point the stream is known as Madison River.

The wall which has accompanied the Firehole on the west, with great persistence, and which has grown steadily higher as the stream-level has declined, develops here into a cliff 1,500 or 1,800 feet in height. The ridge on the right, too, approaches the river and becomes precipitous. The river is thus closely confined between two rocky walls forming its upper cañon. This, though close and rocky, is not difficult to traverse. It extends about 8 miles down the river from the mouth of the Gibbon, when it terminates abruptly, and the river flows on in its westward course down a broad, timbered valley.

The region lying west of the Firehole has, in general, the form of an elevated plateau from 8,000 to 9,000 feet above the sea, densely timbered, cut by numerous cañons, and yet containing very little water. It is floored with volcanic rock, and, as is commonly the case, the streams quickly find their way down beneath the surface, where they flow, finally emerging at the base of cliffs in the form of huge springs.

CLIMATE.

This region has a climate essentially its own, differing markedly in many respects from that of any other part of the West. Its atmosphere is moister, its rainfall greater, its mean annual temperature lower than of any other extensive portion of that region, and reciprocally it is better clothed with vegetation, especially with large timber. The forest-covered areas have been indicated in the above description of the topography. It may be added that of the area of the Park—3,312 square miles—no less than 2,751 square miles, or 83 per cent., are covered with dense forests. This region, with the adjacent parts of Idaho and Wyoming, contains the most heavily-timbered area in the West, with the exception of parts of Oregon and Washington Territory lying west of the Cascade Range. These conditions of temperature, moisture, and vegetation will be easily understood when one takes into account the

Index and Pilot Peaks.

great altitude of the Park, which averages 8,000 feet, the latitude 44° to 45°, and the presence of the Yellowstone Range on its eastern border, which acts as a great barrier to the air-currents, forcing them to disgorge whatever moisture they may have accumulated upon the region lying at their western base.

We have no long series of meteorological observations in the Park or in its neighborhood. Our conclusions are necessarily based upon a few observations scattered about here and there, and, though they are amply sufficient to give a general idea of the climate, they give no detailed knowledge, and none whatever directly concerning the winter season.

The climate is, as regards temperature, sub-arctic. The winter begins with September and ends only in June, and frosts are not only liable to occur but actually do occur every month of the year. The following statement of tri-daily and minimum temperatures in August, September, and October illustrates in a general way the range of temperature in the Park during those months:

SHOSHONE GEYSER BASIN.

[Latitude, 44°.21′; longitude, 110°.48′; elevation, 7,837 feet.]

Date.	Temperature.			Relative humidity.			Min. temp.	Remarks.
	7 a. m.	2 p. m.	6 p. m.	7 a. m.	2 p. m.	6 p. m.		
August 14	.....	74	71	.....	.....	56	.....	Atmosphere very smoky.
15	48	70	60	86	55	76	43	Rain in evening.
16	52	59	56	100	88	88	50	Rain last night and all day.
17	51	62	52	93	79	93	47	Do.
18	49	60	49	93	78	100	44	Rain in morning.
19	47	59	57	93	82	81	40	Rain all night; clear in day.
20	40	63	59	100	75	94	36	Clear.
21	44	68	65	100	72	.....	40	Do.
22	47	68	62	100	80	79	44	Rain in afternoon.
23	57	63	62	88	75	89	53	Rain all day.
24	48	71	67	93	60	68	43	Clear.
25	47	69	67	93	52	57	42	Do.
26	39	.....	.....	91	.....	.....	34	Do.

UPPER GEYSER BASIN.

[Latitude, 44°.28′; longitude, 110°.51′; elevation, 7,373 feet.]

August 27	40	75	67	.....	.....	.....	.....	Clear.
28	37	.....	.....	.....	.....	.....	33	Do.
29	54	59	67	87	77	61	.....	Do.
30	44	73	65	84	37	55	35	Do.
31	46	.....	72	.....	.....	34	33	Do.
September 1	36	.....	75	90	.....	35	31	Do.
2	41	.....	.....	100	.....	.....	34	Do.
8	.....	.....	33	.....	.....	.....	.....	Snowed all night and day; 6 inches fell.
9	27	.....	.....	.....	.....	.....	24	Clear and windy.
10	28	50	36	.....	58	.....	24	Clear.
11	26	64	.....	.....	53	.....	23	Do.

WHITE MOUNTAIN HOT SPRINGS.

[Latitude, 44°.58′; longitude, 110°.42′; elevation, 6,387 feet.]

September 16	33	.....	44	.....	.....	100	.....	Clear.
17	32	.....	.....	.....	.....	.....	26	Do.
18	44	.....	56	.....	.....	.....	36	Rain in evening.
19	45	.....	49	.....	.....	.....	38	Clear.
20	37	61	49	100	61	93	32	Do.
21	35	.....	54	.....	.....	65	28	Do.
22	39	45	36	.....	.....	81	39	Weather threatening.
23	25	.....	.....	.....	.....	.....	18	Snowed all afternoon and night and the following day; 8 inches fell.

LOWER GEYSER BASIN.

[Latitude, 44°.35′; longitude, 110°.50′; elevation, 7,236 feet.]

Date.	Temperature.			Relative humidity.			Min. temp.	Remarks.
	7 a. m.	2 p. m.	6 p. m.	7 a. m.	2 p. m.	6 p. m.		
September 30	32	.....	33	.....	.....	.....	.....	Snowed all night and day.
October 1	32	.....	40	.....	.....	.....	30	Flurries of snow all day.
2	28	46	37	.....	.....	.....	21	Clearing.
3	20	.....	39	.....	.....	.....	8	Clear.
4	19	.....	35	.....	.....	.....	16	Weather threatening, with flurries of snow.
5	21	.....	38	.....	.....	.....	18	Do.
6	24	.....	44	.....	.....	.....	22	Do.
7	38	.....	50	.....	.....	.....	29	Do.
8	30	.....	44	.....	.....	.....	30	A little snow last night.
9	42	.....	51	.....	.....	.....	33	Snow last night.
10	24	.....	33	.....	.....	.....	21	Flurries of snow.
11	25	.....	45	.....	.....	.....	23	Clear.
12	41	.....	39	.....	.....	.....	31	Snowing most of day.
13	37	.....	.....	.....	.....	.....	31	Do.

MEANS OF ACCESS, ROADS, TRAILS, ETC.

There are well-marked roads or trails connecting most of the points of interest in the Park, while in cases where there are none the character of the country is such that one has no trouble in going wherever he pleases, so that few parties have taken the trouble to follow any established trail, preferring to select their own routes.

From Bozeman to the Mammoth Hot Springs, on Gardiner's River, there is an excellent wagon road. At the springs there are several log houses, used in part for the entertainment of travelers. The sleeping accommodations at present are very primitive, consisting, in lieu of a bedstead, of 12 square feet of floor-room. Every guest is expected to provide his own blankets. We are too far west for bed linen. Cooking arrangements are correspondingly simple. The frying-pan is the universal utensil, serving to cook everything from bread to meat. The fare is simple, and remarkable for quantity rather than quality or variety.

From these springs an excellent pack-trail starts up the Yellowstone, also a wagon trail to the Geyser Basins on the Firehole River. The former follows up Gardiner's River and its eastern fork for several miles, then strikes off across the plateau of the Third Cañon towards the Yellowstone, reaching it at Baronette's Bridge. On the plateau it is joined by a trail coming from the mouth of Gardiner's River. At the bridge it forks, one branch crossing the river and following up the East Fork of the Yellowstone. From the latter a trail goes up Slough Creek, crossing at its head to the Rosebud. Another passes up Soda Butte Creek to the mines on the head of Clark's Fork of the Yellowstone, which are at the base of the two prominent mountains—Index and Pilot Peaks—while the main trail, a few miles above the mouth of Soda Butte Creek, leaves the East Fork, climbs the abrupt mountain on the west, and continues southward along the divide between the Yellowstone and its East Fork for several miles, finally descending to the head of Pelican Creek, which it follows down nearly to Yellowstone Lake.

The portion of this trail between the valley of the East Fork and that of Pelican Creek is very faint and difficult to follow. Indeed, it is here noted rather as a practicable route than one as yet marked by a trail.

The trail up the Yellowstone, on leaving the bridge, continues on the west side of the river, and at first quite near it. It crosses Tower Creek just above the Falls. Then it ascends, by a very easy grade, the long

Return from an Elk Hunt.

spur which separates Antelope from Tower Creek. Passing the shoulder of the spur, where it turns to a southward trend, the trail begins a general descent towards the gorge of Carnelian Creek. For several miles it continues this course on the side of the mountain, crossing the sharp gulches of two or three mountain torrents, and finally reaches the bed of the cañon but a short distance below the head of the creek. Then it goes up a steep ascent to the divide, which has an elevation of 8,867 feet. On the summit is a spring, the water from which drains either way, and which affords an excellent camping place for the ascent of Mount Washburn or Dunraven Peak.

Thus far the trail is excellent, with the exception of the last half dozen miles. There are steep hills at the crossing of two or three gulches, noted above, and the final hill is very steep; also, about the crossing of Carnelian Creek, there are bad, marshy spots.

South of the Washburn Divide the trail skirts the base of the mountains westward, gradually descending to the valley of Cascade Creek. It then follows this valley, which is quite marshy in many places, down to the neighborhood of the Falls of the Yellowstone. It crosses Cascade Creek just above Crystal Fall. Thence to Yellowstone Lake it follows the river quite closely on the west bank.

The Yellowstone is fordable at ordinary stages of water at a number of places. At a ranch known as Henderson's, a few miles below the mouth of Gardiner's River—at the mouth of Blacktail Deer Creek, in the Third Cañon—at a point one mile above Baronette's Bridge, just below the ruins of a second bridge, and in the section between the Upper Fall and the lake, it is easily fordable on every riffle.

There is a well-marked trail completely around the lake, most of the way following its shore quite closely. It turns off from the river-trail, going east, above the Upper Fall, and bears gradually away from the river, crossing Pelican Creek a mile or more above its mouth and reaching the lake first at the head of Mary's Bay. It rounds Steamboat Point, hugging the shore closely. At the mouth of Turbid Creek it is joined by the trail which comes down Pelican Creek. Down the east side of the lake it is well marked, running on the shore or near it, though for long distances it may be out of sight, owing to the dense timber. On account of the marshy nature of the valley of the Upper Yellowstone, the trail has to make a long detour, several miles up it, to get across, and then returns to the lake to avoid crossing a mass of heavy hills which extend to the lake on the south. After leaving the east side of the valley of the Upper Yellowstone, the trail is much less plainly marked. Indeed, from that point on to the springs on the west arm of the lake, there is little sign of travel. The route generally followed skirts the south and west sides of the south arm, passing around the north base of Flat Mountain and the head of Flat Mountain arm. Thence it crosses to the head of the west arm, striking it quite near the group of Hot Springs. Thence the trail, again strongly marked, hugs the shore quite closely around to the foot of the lake.

Returning now to the Mammoth Hot Springs, let us trace the Norris wagon road to the Geyser Basins. This road was built by Col. P. W. Norris, the superintendent of the Park, in the summer of 1878. The route selected is an excellent one, being very direct, involving few hills, and but little work besides clearing out living and fallen timber and corduroying marshy spots.

Leaving the springs the road goes up directly over a divide to the valley of the East Fork of Gardiner's River. Here is a steep hill, sidling in some places and densely timbered. The road is, however,

well built here, much time and labor having been bestowed upon it. Then it goes southward down this valley, crossing this and the Middle Fork, and then following up Obsidian Creek. All this part has involved but little work, the country being open and clear of timber. Some marshy places have required bits of corduroy. In Obsidian Cañon, however, which is very narrow, much chopping and some building were required, and at its head a long section required to be corduroyed. Following this is a few hundred yards which had to be blasted out of the side of an obsidian cliff and built up out of fragments of this rock. Then it skirts Beaver Lake, and crosses the divide at its head, to the waters of Gibbon River. The ascent of this divide on the north is quite steep. Then the road skirts Gibbon Lake and follows down Gibbon River to the Geyser Basin. Here it leaves the river and crosses the Basin, reaching the stream again only at the head of its cañon, thus cutting off a large bend of the river. After following the river through its cañon it leaves it, gradually bearing away to the southwest, and reaches the Firehole a few miles below the Lower Geyser Basin. It follows this stream quite closely to the Upper Basin, where the road at present terminates.

A second wagon road within the Park was built by General Howard's command, in the campaign against the Nez Percés, in 1877. This comes up the Madison River, through its upper cañon, crosses Gibbon River at its mouth, and on reaching the mouth of the East Fork of the Firehole it turns up it, crosses the divide, and goes down to the Yellowstone, reaching it at the Mud Geysers. For a distance of about 4 miles below the mouth of East Fork these roads are coincident. The Howard road is an excellent one, excepting that at several places on East Fork it is very marshy, and that the ascent to the divide on the west involves a very long, steep hill.

General Howard also cut a road down the Yellowstone from the Mud Geysers to Gardiner's River, following, in most places, the route of the trail. This, however, is practically impassable.

While numerous parties have crossed, from various points on the Yellowstone River and Lake, and from Heart Lake, to the Geyser Basins on the Firehole, they have left little or no trail to mark their course. All routes are possible, and the country is such that any one possessed of ordinary woodcraft can make his own trail as easily as he can follow one.

From the Geyser Basins a well-marked trail leads up the Firehole nearly to its head and crosses thence to Shoshone Creek, which it follows down to the Shoshone Geyser Basin at the west end of Shoshone Lake. Thence it skirts the west end of the lake, and the south side, crosses Lewis Fork at the foot of Shoshone Lake, and follows the latter stream down to the forks of the Snake.

Lewis Fork and the Firehole are fordable almost anywhere at ordinary stages of water, and, of course, there is no trouble about the smaller streams of the Park.

The above enumeration covers all the traveled roads and trails. In conclusion it may be said that there are few parts of the Park which cannot be traversed easily by saddle and pack animals without regard to trails. Dense living and fallen timber and marshy areas form the chief obstacles to getting about, and these can easily, in most cases, be avoided.

DEPARTMENT OF THE INTERIOR.

U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES, F. V. HAYDEN, U. S. GEOLOGIST IN CHARGE.

YELLOWSTONE NATIONAL PARK.

Primary triangulation by A. D. Wilson.

Secondary & topographical topography by Henry Gannett, M.

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